For Editorial Contents see page 227

PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION.

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

TEMPORARY OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 18 & 20, COMPTON ROAD, HAYES, MIDDLESEX.

VOL. 149—No. 3868. *LONDON: FRIDAY, MARCH 1, 1940.* *Registered at the General Post Office as a Newspaper* PRICE 1s. BY FOREIGN POST 1s. 2½d.

Engineering Library MAR 25 1940

S.E.A. RINGS AND SYNTHA PACKINGS 683
LONG LIFE WITH LOW FRICTION
RONALD TRIST & CO. LTD.
BATH ROAD, SLOUGH

INFINITELY BETTER
SPRINGS
SUPER GRADE SPRINGS OF EVERY DESCRIPTION FOR EVERY PURPOSE
On Admiralty, War Office, and Air Ministry Lists. Established 1821.
ROBERT RILEY LTD. 9089
Milkstone Spring Works, Rochdale. Tel. 2572

J. & E. HALL REFRIGERATION
FOR LAND & MARINE PURPOSES
LIFTS AND ESCALATORS
J. & E. HALL LTD., ENGINEERS, DARTFORD, KENT.
Telephone: Dartford 3456.
London Office: 10, ST. SWITHINS LANE, E.C.4.
Telephone: MANSION HOUSE 9811. 755

DYSON TRAILERS
R. A. DYSON & CO., LTD.,
GRAFTON STREET, LIVERPOOL 785
Models to carry from 3 cwts. to 150 tons.

TAPER PINS
SPLIT & SOLID. LARGE STOCKS.
H. FORDSMITH LTD.,
Hadfield Street Works, Cornbrook, MANCHESTER, 16,
TRAfford Park 0789. 793

GLASS For Machinery
BUTTERWORTH BROS., LTD., 9753
Newton Heath Glass Works, Manchester.

HYDRAULIC PLANT FOR RUBBER AND PLASTICS
T. H. & J. DANIELS LTD.
STROUD, GLOS. Phone: 461/2/3.

SPENCER - BONECOURT
Patent Waste Heat Boilers
32, Farringdon Street, London, E.C.4. 868

LOCOMOTIVES
STEAM OR DIESEL
HUDSWELL CLARKE & Co. LTD.
RAILWAY FOUNDRY, LEEDS.
London Office: 46, Victoria St., S.W.1.
Telephone: Victoria 1133 8559

YARROW
& CO. LTD.,
GLASGOW
SHIPBUILDERS
MARINE ENGINEERS 848
LAND AND MARINE BOILER MAKERS

CRADLEY BOILERS
CRADLEY BOILER CO., LTD., 639
CRADLEY HEATH, STAFFS.

PETER BROTHERHOOD
PETERBOROUGH LTD.
STEAM ENGINES AND TURBINES,
GAS AND OIL ENGINES,
AIR COMPRESSORS,
REFRIGERATING PLANT,
See advertisement, Page 27, Feb. 9. 6938

FRICTION CLUTCHES
All Types. *Satisfaction Guaranteed.*
W. R. ANDERTON & CO.,
Clutch Specialists,
CASTLETON, ROCHDALE 506

CRANES
GEORGE RUSSELL & CO., LTD.,
Motherwell. 816

DREDGERS
OF ALL TYPES
FERGUSON BROS. (Port-Glasgow) LTD.
PORT-GLASGOW 626

"DELTA" BRAND NON-FERROUS METALS AND ALLOYS
THE DELTA METAL CO. LTD.
LONDON and BIRMINGHAM

PLENTY
& SON LIMITED, NEWBURY
MARINE ENGINEERS.
STEAM ENGINES
TO 1500 I.H.P. 597
FOR ALL CLASSES OF VESSELS
STERN GEARS
FOR DIESEL MOTOR VESSELS AND COMPLETE INSTALLATIONS UNDERTAKEN.
COX PATENT ROTARY DISPLACEMENT PUMP

SPECIAL MACHINES MADE TO ORDER
Parts and repairs
Erection of Plant
Millwrights work 9963
THOMAS HUNT & SONS
Bridge Road West BATTERSEA, S.W.11.

BABCOCK

RAPIER
WALKING DRAGLINES
RANSOMES & RAPIER LTD.
Ipswich England 548
Builders of Europe's Largest
EXCAVATORS

BAXTERS
"PATENTED KNAPPING MOTION"
STONEBREAKERS
and ALLIED SPECIALITIES 756
W. H. BAXTER, Ltd., Leeds, 12.

MUREX Electrodes
625
MUREX WELDING PROCESSES LTD.,
HERTFORD RD., WALTHAM CROSS, HERTS.

MACROME
—Toughest Tools in the World—
MACROME 9934
LIMITED
Hay Mills, Birmingham. Telephone: Vic. 1283
"Z Dept."

MACHINE WORK.
TURNING, FACING, GRINDING, etc.
PLANING UP TO 12ft. 0in. by 4 ft. 0 in. by 4 ft. 0 in.
WELDING AND CONSTRUCTIONAL WORK.
EXPERIMENTAL WORK.
ROSSER & RUSSELL, LTD.,
QUEEN'S WHARF, HAMMERSMITH, W.6.
'Phone: RIV. 4416. 9211

ELECTRIC
CONTROL GEAR
VLASTO, CLARK & WATSON
STOCKTON HEATH, WARRINGTON 739

9796 **VALVE**

MOSS
A name of fame for highest quality machine cut
GEARS
THE MOSS GEAR CO. LTD.
Crown Works, Tyburn, Birmingham. 2041

Send for NEW Catalogue
COOPER SPLIT ROLLER BEARINGS
KING'S LYNN 708 NORFOLK

SAND FILTERS
JOHN THOMPSON
(KENNICOTT WATER SOFTENERS) LTD.,
WOLVERHAMPTON.
Estd. over 40 Years. 744

"The machine with a BRAIN"
SCIAKY
SPOT WELDERS
SLOUGH —— 22342

LA MONT WASTE-HEAT BOILERS
Particulars from:— 677
LAMONT STEAM GENERATOR LTD.
Quadrant House, 55, Pall Mall, London, S.W.1.

TUBES LTD.
ASTON, BIRMINGHAM.
Manufacturers of 9857
WELDLESS STEEL BOILER TUBES · COLD DRAWN TUBES
FOR THE ENGINEERING INDUSTRY

ALLDAYS & ONIONS
685 BIRMINGHAM, LTD.
FANS
See page 16.

PISTON RINGS
HARRY LANCASTER & CO. LTD.
1/3, BRIXTON ROAD, LONDON, S.W.9.

Alfred Herbert Ltd., Coventry
PAY BEST PRICES for SECONDHAND MACHINE TOOLS in good condition, by first-class makers.—Write, wire, or phone, and our representative will call. 'Phone 88781 Coventry. Telegrams LATHE, Coventry. W 305

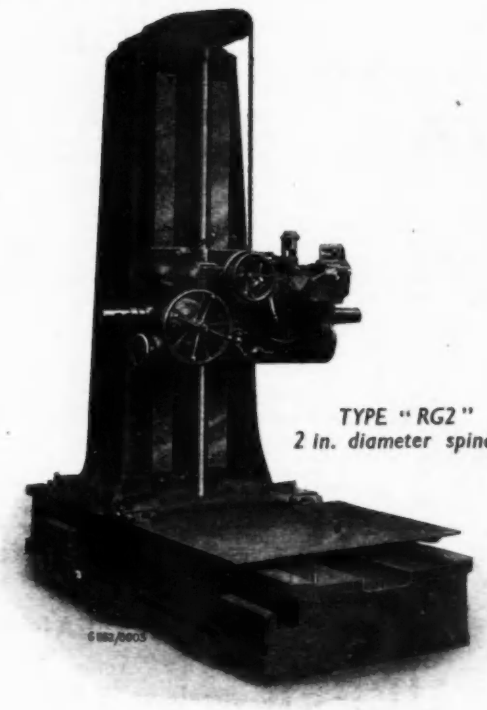
VALUE

ASQUITH

HORIZONTAL DRILLING, BORING & MILLING MACHINES

TYPE "NHB1" 8 in. spindle machine

BUILT in accordance with the recognised Asquith high standard of quality, accuracy and durability these machines embody advanced features which place them well in the forefront of contemporary design. Made in sizes from 1½ in. up to 12 in. diameter spindle.



TYPE "RG2"
2 in. diameter spindle.

Fully described in New Brochure R74
Write for YOUR COPY today

Send your enquiries to:

WILLIAM ASQUITH LIMITED, Park Works, HALIFAX, ENGLAND

Telephone :—61258/9, 61250. **Telegrams :—Drill, Halifax.**

SOLE Distributors for the British Isles :—

DRUMMOND (SALES) LIMITED, KING EDWARD HOUSE, NEW ST., BIRMINGHAM, 2

Other Agents in all the Leading Countries.

592

NEW METHOD OF CONSTRUCTING FRENCH CURVES.

By B. HAGUE, D.Sc.

IN a paper published in 1938, Professor Fritz Emde* described some French curves of a new and interesting design that appears to be unknown in this country. The writer has prepared a set of these curves and has found them to be very useful in practice; their properties should certainly be more widely known. It was thought, therefore, that an account of Professor Emde's work would be acceptable to draughtsmen and others who use such curves, since the journal in which his paper appeared is one that is not readily available to engineers in Great Britain, even in normal circumstances. At the same time, some general comments are made on the principles by which French curves may be designed.

The method used for drawing a graph depends upon its radius of curvature and the rate at which that radius changes. When the radius changes but slowly from point to point along the graph, it is easily fitted by circular arcs, these being drawn by means of compasses when the radius is small and by circular templates when the radius is large. If the rate of change is too great for the circular arc approximation to be suitable, but the graph remains fairly flat, the use of "ship curves" or a bent spline is preferred. In all other cases, when the rate of change is still greater, and whether the graph be flat or well rounded, it is necessary to use French curves. It is, unfortunately, a common experience to find that few such curves are really satisfactory for their intended purpose; drawing becomes a slow and tedious process of fitting short lengths of the graph with selected portions of the French curve profile, requiring considerable care and patience. The French curves usually obtainable have several defects, the most important of which is that the profile is quite arbitrary and the curvature changes in no regular way; in some cases the curve is even inflected or S-shaped, a form that is practically useless. Many curves have both convex and concave edges, but the latter are rarely used in practice, even with pencil, and are almost impossible to use with ink without serious danger of blotting. Curves are often tapered off to a radius that is much too small; it is hardly practicable to work a drawing pen round a contour with a radius less than 1 cm.

The usefulness of any small portion of a French curve depends on (i) the radius of curvature at the middle of the selected arc, and (ii) the rate at which the radius changes from one end of the arc to the other. This rate should be regular, should follow some definite mathematical law, and should be either a continuous increase or decrease as we proceed along the curve in a given direction; above all, the rate of change should not reverse, *i.e.*, the curve should not be inflected. It follows, therefore, that the ideal profile should be a portion of a spiral which has a simple mathematical relation between the radius of curvature—or its reciprocal, the curvature—and the distance measured along the arc of the curve. Such a relation is known as the intrinsic equation of the curve. The simplest spiral curve is the Archimedean spiral with the polar equation $\frac{r}{a} = \theta$, the form being shown in Fig. 1. This curve starts horizontally at the origin and equally-spaced radii vectors grow in arithmetical progression. The intrinsic equation is not, however, of a simple kind, and the profile, in spite of its easy construction, is not particularly useful in practice.

The logarithmic spiral with the polar equation $\frac{r}{a} = e^{m\theta}$, where a and m are constants, is shown in Fig. 2. The radius vector is a when $\theta = 0$, and equally-spaced radii vectors grow in geometric progression at a rate proportional to m; in the example shown, $a = 10$ and the growth is 10 per cent. per 20 deg. This curve has the important property that the difference between the radii of curvature at two points on the curve is proportional to the length of arc separating them. Although French curves with this profile are on sale in Germany, they are unknown here. Another useful curve is the clothoid or Cornu spiral in which the cartesian co-ordinates are $x \propto C(z)$ and $y \propto S(z)$, where $C(z)$ and $S(z)$ are the Fresnel integrals encountered in the theory of optical diffraction. Numerical values of these functions are given in tables.* The property of the clothoid is that the difference between the curvatures at two points on the curve is proportional to the length of arc separating them. Emde has constructed a set of curves on this plan which are especially useful for smaller curvatures, *i.e.*, for the larger radii of curvature. The simple form of the spiral is shown in Fig. 3, page 216.

Coming now to the principal problem, let R denote the radius of curvature and $\frac{1}{R}$ the curvature at any point situated at a distance s along the arc of a curve from an arbitrary starting point upon it, as in Fig. 4, page 216. The rate of change of curvature with arc is

$$\frac{d\left(\frac{1}{R}\right)}{ds}$$

and this, expressed as a fraction of the curvature at any point, is

$$R\frac{d\left(\frac{1}{R}\right)}{ds} = R\frac{d\left(\frac{1}{R}\right)}{dR}\frac{dR}{ds} = -\frac{1}{R}\frac{dR}{ds} \quad (1)$$

i.e., the fractional rate of change of curvature is numerically equal to the rate of change of radius of curvature as a fraction of that radius and of opposite sign. In the particular case of a circle, the radius of curvature and the curvature are both constant, so that their rates of change are zero. Although the logarithmic and Cornu spirals both have simple intrinsic relations between R and s, their practical limitation as profiles for French curves is that the fractional rates of change defined above gradually become smaller and smaller, in the former case for large radii of curvature and in the latter case for small ones. In other words, for these conditions the curves gradually approximate to circular shape, as will be appreciated from Figs. 2 and 3. In the ideal form of French curve circularity should not be approached and these fractional rates of change should be constant at all points on the profile. If equation (1) is written equal to a constant $\frac{1}{L}$, where L has the dimensions of length; then by integrating between two points on the curve defined by arcs s_1 and s_2,

$$-\int_{R_1}^{R_2}\frac{dR}{R} = \int_{S_1}^{S_2}\frac{ds}{L},$$

or

$$\log\left(\frac{R_1}{R_2}\right) = \frac{(S_2 - S_1)}{L} \quad . \quad . \quad (2)$$

is the relation between successive radii of curvature and arc length. From this it follows that the radii of curvature at any two points situated an equal distance apart on the curve are in the same ratio. This should be compared with the logarithmic spiral in which $R_2 - R_1 = m(S_2 - s_1)$, *i.e.*, equi-spaced points correspond to equal differences in radii of curvature; and the clothoid in which $\left(\frac{1}{R_2}\right) - \left(\frac{1}{R_1}\right) = B(s_2 - s_1)$ where such points correspond to a constant difference in curvature.

In Fig. 4, the tangent to the curve may be drawn

Fig. 1.

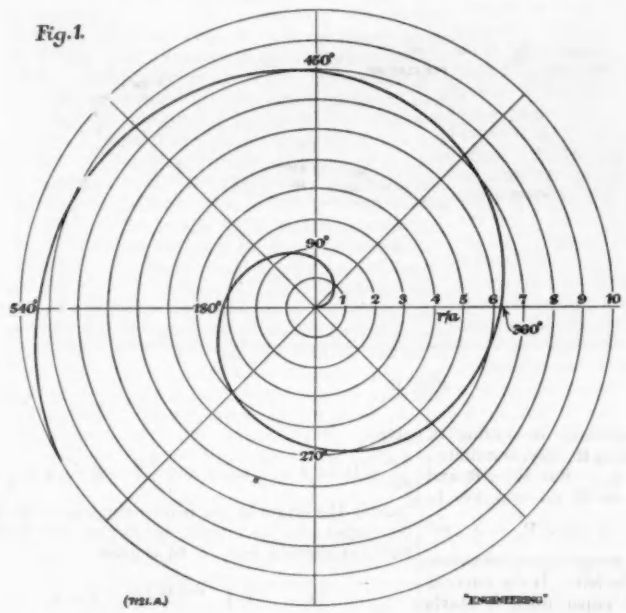
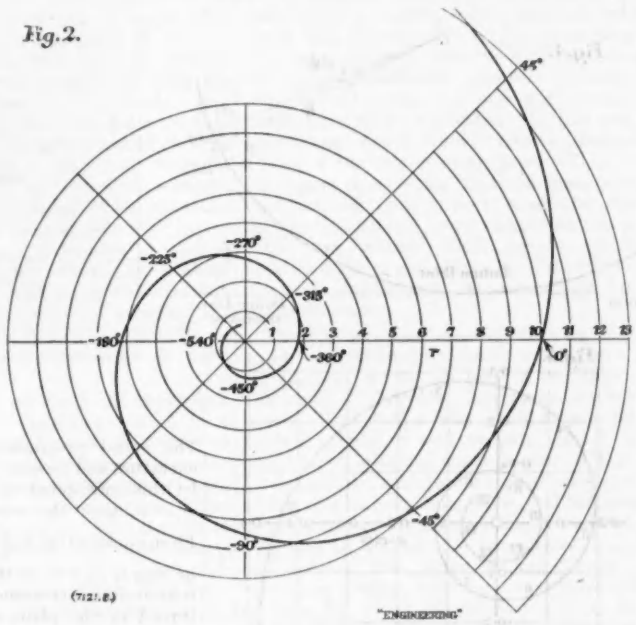


Fig. 2.



* "Kurvenlineale," *Zeitschrift für Instrumentenkunde*, vol. 58, pages 409-411 (1938).

* See, for example, E. Jahnke and F. Emde, *Funktionentafeln*, 3rd edn., page 35 (1938). For their theory, see J. Edwards, *Integral Calculus*, vol. 1, pages 566-7 (1921). The integrals are defined as $C(z) = \int_0^v \cos\frac{\pi v^2}{2} dv$ and $S(z) = \int_0^v \sin\frac{\pi v^2}{2} dv$, the tabulated parameter being $z = \frac{\pi v^2}{2}$ *i.e.*, v^2 right angles.

THE CONSTRUCTION OF FRENCH CURVES.

Fig. 3.

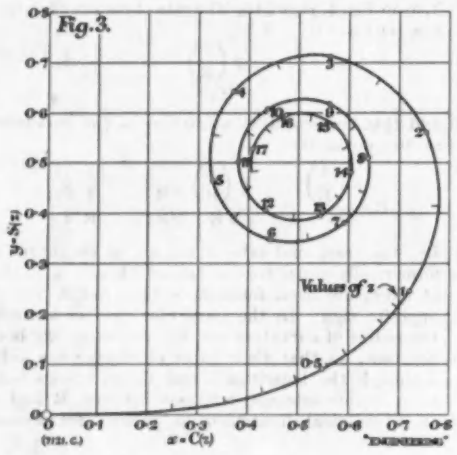


Fig. 4.

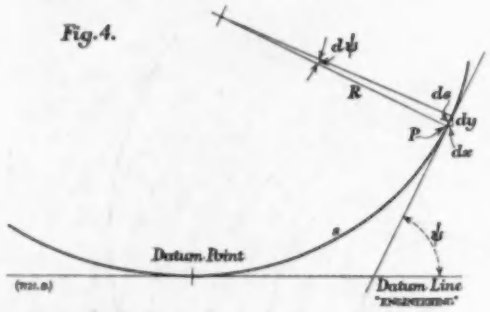
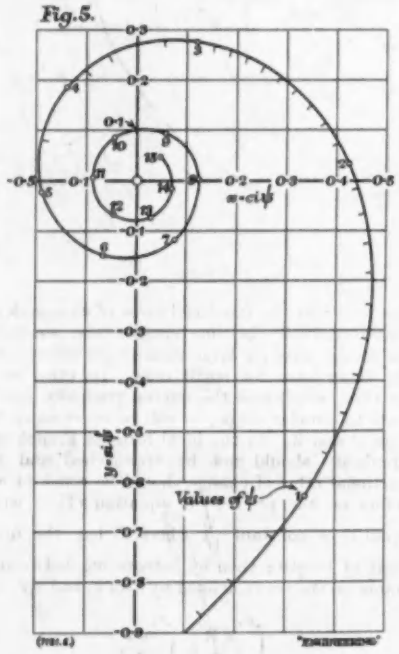


Fig. 5.



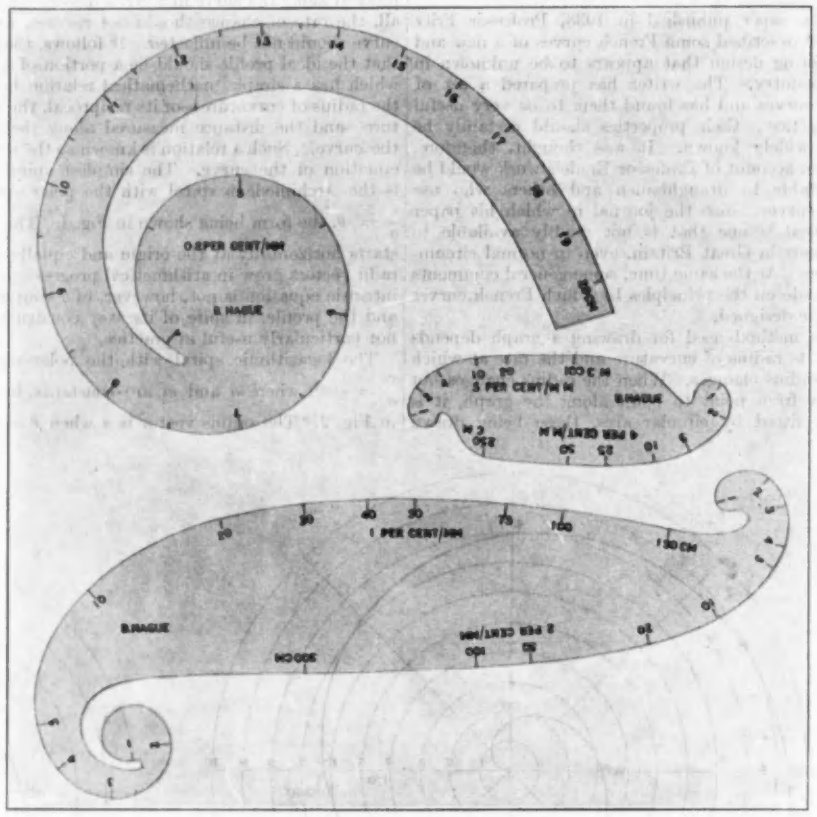


Fig. 6.

at the datum point and a second tangent at any point P distant by an arc s from the first. Let ψ be the angle turned through by the tangent in moving from one position to the other; then, geometrically,

$$d s = \mathrm{R}\, d\psi = -\frac{\mathrm{L}\, d\mathrm{R}}{\mathrm{R}}$$

since equation (1) gives $-\dfrac{d\mathrm{R}}{\mathrm{R}\,d s} = \dfrac{1}{\mathrm{L}}$. Integrating between two points,

$$\int_{\psi_1}^{\psi_2} d\psi = -\mathrm{L}\int_{\mathrm{R}_1}^{\mathrm{R}_2} \frac{d\mathrm{R}}{\mathrm{R}^2}$$

or

$$\psi_1 - \psi_2 = \frac{\mathrm{L}}{\mathrm{R}_1} - \frac{\mathrm{L}}{\mathrm{R}_2}. \qquad . \quad . \quad (3)$$

The spiral progressively increases in radius of curvature and becomes flat when R_1, say, is infinite; let this correspond to $\psi_1 = \psi_\infty$. Put $\mathrm{R}_2 = \mathrm{R}$ and $\psi_2 = \psi$, then the equation is $\mathrm{R}\,(\psi - \psi_\infty) = \mathrm{L}$. From equation (2), $\log\left(\dfrac{\mathrm{R}_1}{\mathrm{R}_2}\right) = \infty$ when $\mathrm{R}_1 = \infty$, requiring $s_1 = -\infty$, so that the point of zero curvature is at an infinite distance to the left. If the curve is turned in the plane of the paper until it starts horizontally from this point; then $\psi_\infty = 0$ and the simplest intrinsic equation* for a curve with constant fractional rate of change of curvature is

$$\mathrm{R}\,\psi = \mathrm{L}. \qquad . \quad . \quad . \quad (4)$$

To express the curve in rectangular co-ordinates and plot it, Fig. 4 shows that $\dfrac{d x}{d s} = \cos\psi$ and $\dfrac{d y}{d s} = \sin\psi$. Remembering that $\mathrm{R} = \dfrac{d s}{d\psi}$, equation (4) gives

$$\frac{d x}{d\psi} = \mathrm{R}\cos\psi = \frac{\mathrm{L}}{\psi}\cos\psi \text{ and } \frac{d y}{d\psi} = \mathrm{R}\sin\psi = \frac{\mathrm{L}}{\psi}\sin\psi$$

Taking the origin as the point upon which the spiral converges after an infinite number of convolutions; then integrating from ∞ to ψ gives

$$x = -\mathrm{L}\int_{\psi}^{\infty} \frac{\cos\psi}{\psi} d\psi = \mathrm{L}\,\mathrm{ci}\,\psi$$

and

$$y = -\mathrm{L}\int_{\psi}^{\infty} \frac{\sin\psi}{\psi} d\psi = \mathrm{L}\,\mathrm{si}\,\psi,$$

where ci ψ and si ψ are defined as the cosine and sine integrals. They are expressible in series form and numerical values are given in tables.* Taking ψ as a parameter, x and y can then be calculated for a chosen constant value of L; the radius of curvature is $\mathrm{R} = \dfrac{\mathrm{L}}{\psi}$, and the curvature $\dfrac{1}{\mathrm{R}} = \dfrac{\psi}{\mathrm{L}}$. The canonic form of the spiral is shown in Fig. 5 for the case of $\mathrm{L} = 1$ co-ordinate unit, corresponding values of $\psi = \dfrac{1}{\mathrm{R}}$ being marked against the curve.

If the fractional rate of change of curvature, constant along the whole curve, is p per cent. per millimetre, equation (1) gives

$$-\frac{d\mathrm{R}}{\mathrm{R}\,d s} = \frac{p}{100} = \frac{1}{\mathrm{L}},$$

so that $\mathrm{L} = \dfrac{10}{p}$ in cm. By choosing various constant values of p, *i.e.*, of L, the scale of the spiral can be altered and profiles with differing degrees of flatness or roundness are obtained. The following values are selected:—

p =	0·2	1	2	4	5 per cent. per mm.
L =	50	10	5	2·5	2 cm.

The resulting set of French curves made in transparent celluloid is shown in Fig. 6. The figures near the working edges are radii of curvature in

* This relation should be contrasted with the corresponding forms for the logarithmic and Cornu spirals. For the former it is easy to show (Edwards, *loc. cit.*, page 556) that $s = \mathrm{A}\,e^{m\psi}$, where A is a constant, so that

$$\mathrm{R} = \frac{d s}{d\psi} = m s = m\mathrm{A}\,e^{m\psi}.$$

For the latter, the relation (Edwards, *loc. cit.*, page 566) is $k s^2 = \psi$, where k is a positive constant and ψ is positive only. From this

$$\mathrm{R} = \frac{d s}{d\psi} = \frac{1}{2 k s} = \frac{1}{\sqrt{(4 k \psi)}}.$$

Each value of ψ gives two values of s, one positive and one negative, the former only being shown in Fig. 3, symmetrical about the line $\psi = 0$. Taking this as the x axis, then

$$x = \int \cos\psi \,.\, d s = \int_0^s \cos k s^2 .\, d s$$

and

$$y = \int \sin\psi \,.\, d s = \int_0^s \sin k s^2 .\, d s,$$

which are the Fresnel integrals cited above.

* *Loc. cit.*, pages 6-9.

cm., and in no case do these go below 1 cm. The set has recently been extended by the preparation of additional curves with $p = 0{\cdot}5$, $2{\cdot}5$ and $3\frac{1}{2}$ per cent. per mm., *i.e.*, L = 20, 4 and 3 cm. This set of curves has proved to be much more convenient than those normally obtainable. Their regular change of curvature and definite mathematical form makes it possible to draw quite long arcs of a graph at a single stroke, 10 cm. being not unusual. The task of fitting a graph is both easy and quick, the scale of radii assisting the process considerably. Finally, thanks are due to Professor Emde for bringing his paper, upon which the present article is based, to the writer's notice; and to Dr. A. J. Small, of Glasgow University, for his skill and patience in preparing Fig. 6.

EFFICIENCY IN DOCUMENTATION.

By S. C. BRADFORD, D.Sc.

DURING the last Great War, the vital necessity of documentation compelled attention. For lack of information, valuable time was wasted, costly experiments were made, and crude apparatus hastily improvised, while accurate descriptions of suitable material, methods and machinery were lying hidden and unknown in dusty volumes in the library. That the deficiency of pre-war documentation was responsible for the prolongation of the struggle, with consequent loss of human life, was admitted. Since 1918, much progress in the art has been made. Two fundamental principles have been grasped, firstly that the task of gathering the information recorded upon a single topic is far beyond the power of any individual, and, secondly, that, by the organisation of many workers, the whole record of human progress must be indexed as the basis of further advance. Much of the development in post-war bibliography has followed the natural course of constituting bureaux or periodicals for the purpose of indexing and making abstracts of the literature of particular subjects. As the result of this progress, the greater part of pure and applied science is now within the scope of one or more of such institutions or periodicals. Moreover, these various agencies have begun to realise the advantage of closer co-operation between themselves, and such collaboration has already been achieved between some groups of bureaux in related fields. Another considerable development has been the gradual realisation of the necessity for the adoption of standard methods as the essential means of efficient co-operation between a number of agencies.

This change has been brought about through the action of the International Federation for Documentation, now recognised as the international centre for the co-ordination of documentation. Thanks to its efforts, and those of its national sections, the list of "Users of the Universal Decimal Classification," published by the British Society for International Bibliography, includes, with its supplement, the titles of upwards of 140 periodicals that have adopted this system. It is obvious that abstracting and indexing periodicals, classified in this manner, can be cut up and amalgamated into a single series, where all titles and abstracts relating to a particular topic fall together under the same classification number, regardless of source or language, and since, according to the system, these abstracts are arranged in chronological order, under each special subject, the history of such a subject may be seen at a glance. As is well known, all items so classified have been accumulated in the Science Library and amalgamated into an index, which contains more than two and a half million cards that are increasing at the rate of about one hundred and fifty thousand annually. This card index is a concrete example of the results of adopting a standard system of classification.

It is evident, therefore, that since 1918 much progress has been made. The need for collaboration has been realised and a measure of co-operation achieved. Doubtless the process will continue with increasing impetus. But, now that we have grasped the fact that, because human progress is based on knowledge, it is essential to index what is known, we may not rest content with partial achievement in this great task, and, in time of emergency, it becomes especially important to eliminate all unnecessary labour and to secure the greatest efficiency, both in documentation, and, as a consequence, in war time effort. If we compare what has been done with what is necessary in order to secure a complete index, we are forced to admit that there is much more to do. Everyone who has given special attention to the study of the bibliography of his special subject knows that the present organisation does not provide complete documentation. Statistical investigation gives figures so unsatisfactory that those who have not studied the data hesitate to accept them.

The primary reason for this incompleteness is the lack of co-operation between existing services. It would appear that the amount of labour being employed would go far to provide a complete index to knowledge in the technical sphere. At present, this labour is wasted through overlapping to a lamentable degree and by the adoption of uneconomic methods. Every student of science knows how every branch of present-day science is related, in greater or less degree, to every other. Progress in any one subject may affect that in any other branch of knowledge. We know that modern science is one, but we have yet to apply that principle to practical documentation. So far, we have been content, for the most part, to attempt to index and abstract original literature from the point of view of each subject separately, and, since papers of value to the investigator in that subject may occur in periodicals devoted to any other subject within almost the whole range of science, this means that the mass of scientific literature, to the extent of some fifteen thousand current periodicals, ought to be searched for papers on one subject. Moreover, the attempt to work in water-tight compartments involves the undertaking of this task in relation to every subject abstracted; it needs merely to state the method to realise the uneconomic nature of the process. Actually, in practice, this labour-wasting procedure is quite impossible and undreamt of.

It is not realised that, although the occurrence of papers of value on a particular subject in a periodical remotely concerned with that subject is rare, the number of such periodicals increases with the remoteness of their relationship, so that such papers form a very considerable portion of the total contributions to the subject. The attempt is made to collect such papers from abstracting periodicals devoted to other subjects. But this method is unsatisfactory for the reason that such periodicals are selective, are not concerned with the subject in question and are classified from another point of view. Further causes of incompleteness are the lack of files of some of the less-known periodicals and the want of funds necessary to pay for the labour involved in so much work. Because of this incompleteness in the indexing of current information, combined with inadequate documentation of past work and lack of uniformity in methods of classification, the inquiry into the present state of knowledge of any special topic, however restricted, involves a bibliographical search lasting from days to months, when only a short while should be needed. In the end, further time is likely to be wasted in costly experiments to discover some fact already recorded, if only its record could have been found. The muddle is aggravated by the creation, from time to time, of new independent bibliographical agencies in fields where other bodies are already working.

Realisation of the unity of science is the key to efficient documentation. Abstracting and indexing must be organised from the standpoint of science as a whole. Yet, it is neither necessary nor desirable to interfere with the organisation of existing services. The experts who are already dealing with the bibliography of their special subjects are likely to be the best people to do it; all that is needed is a change in orientation. It is necessary to grasp that there are two stages in the preparation of a regular service of abstracts in a given field: the first is to collect the papers and the second is to abstract them. It is only the first stage which is so greatly in need of re-organisation, and the necessary change is of the simplest. Instead of attempting the vain task of searching the whole mass of scientific literature from the point of view of each special subject, as many times as there are subjects, let us divide the whole of the literature between the available abstracting bodies, so that each bureau undertakes to make a catalogue entry of each paper of value that occurs in the periodicals allotted to it, whether that paper is of interest to that particular bureau or not. As most periodicals are limited in scope to some particular subject, they could be allocated in such a way that the number of papers in them, that were not within the special scope of a particular abstracting bureau, would not be excessive. Periodicals of more general scope could be catalogued in detail in the first place by one or more of the larger libraries. The Science Library already is issuing a weekly classified catalogue of all the papers of importance in a list of the most important periodicals of general scope.

The titles of the papers, that were not within the purview of the abstracting bureau that catalogued them would be classified roughly in some way by the bureau; a short decimal classification number would be the most convenient symbol. The classified titles, written on slips of uniform size, would then be forwarded to a central body, where they would be arranged in numerical order by a typist and re-dispatched to the abstracting bodies who were concerned with the subjects indicated by the rough classification numbers. Usually, there would be more than one such body, and the slips would have to be duplicated. In this way, every abstracting body would receive automatically a copy of the title of every paper within its scope. The labour of searching the whole mass of scientific literature for each subject would be eliminated and the mechanism would ensure that no paper of value was missed. Each bureau would then consider what papers should be abstracted and the complete classification number would be added to the abstracts.

There is no other way of ensuring that every paper is scrutinised, except by setting up a central organisation, similar to that of the International Catalogue of Scientific Literature, to index the whole. Since such a body would have to deal with applied science as well as pure science, its task would be at least five times as great as that of the International Catalogue, it would duplicate much of the work already being done, and the cost would be prohibitive. We must not forget that abstracting may also be divided into two classes, *i.e.*, general and special. The latter is undertaken, usually by smaller bodies, from some very restricted point of view, for which the ordinary general abstracts are insufficient. The smaller the abstracting body, the more impossible it becomes to survey the whole of the literature, which, in practice, is generally restricted to a few hundred periodicals. It is obvious how helpful a complete series of abstracts uniformly classified would be to such bodies in bringing to their notice likely papers for scrutiny which would not otherwise be found.

The continually-extending adoption of the Universal Decimal Classification has already been mentioned. Its application to the whole of the abstracts and index titles produced under the above scheme would serve to co-ordinate the entries and to ensure that every item was classified in such a manner that it could be found from any standpoint. But it is important to realise that the adoption of a standard system of classification is only a means to an end, namely, complete co-operation between all the abstracting and indexing agencies using the system. Up to the present, the adoption of the Decimal Classification has made possible the formation of the great index in the Science Library, but the fullest advantages have not been reaped by the participating bureaux. They have had the advantage of using the most efficient system of filing and making indexes of any kind, but, in many cases, they have not taken the opportunity of filing, in their own indexes, references to the literature of their own special subjects issued from other sources, and they do not make sufficient use of the index in the Science Library. This index is of special utility in dealing with inquiries, which overlap with other subjects, and with which no special index, restricted to a small field, can cope. Some system is needed for the automatic inter-

change, through a recognised centre, of bibliographies prepared in answer to special inquiries, for the addition of further references, whether from other sources or other subjects.

It will be seen that, while the subject of documentation has progressed enormously since the war of 1914-18, much improvement is still needed. In this further development other countries have been allowed to take the lead. In France, a national documentation centre has been established at the Bibliothèque National, while in Switzerland the experiment has been made of co-ordinating four of the largest administrative libraries, those of the Swiss Railways Department, the Post Office, the Telegraphs and Telephones Department, and the Customs Department. The co-ordination of both library and documentation services has been achieved by the use of the Universal Decimal Classification, and the experiment has been so successful that the process is likely to be extended to the whole forty-nine administrative libraries in the country. When we realise the vital necessity in war time of making use of every scientific means in the quickest and most efficient manner, we see that the greatest possible co-ordination and collaboration in documentation should be achieved without delay.

THE ENGINEERING OUTLOOK.

VI.—Electrical Engineering.—The Light Industry.

Activity in the light section of the electrical-engineering industry as a whole reached a record level in 1939, though this prosperity was by no means equally spread over its various sections. In past years we have taken as an index of activity the consumption of new copper in Great Britain, but it was pointed out in this series last year that such an index took no account of variations in the importance of the different uses to which copper is put. Such information regarding the consumption of copper by uses as can be obtained from the Census of Production reports indicates that, in peace time, these variations are not very great, except over comparatively long periods of time. Copper, however, is an important war metal, and the increased production of brass for shell cases and other military uses undoubtedly invalidates the use of copper-consumption statistics as an index of activity in electrical engineering in time of war. In the first eight months of 1939 the net imports of unwrought copper amounted to 202,188 tons, compared with 179,691 tons in the previous year. Of this increase of 24 per cent., part was undoubtedly accounted for by increased consumption for military uses.

Table I, herewith, shows the employment in the manufacture of electric cables, apparatus and lamps.

Table I.—*Employment in the Electric Cable, Apparatus, Lamps, etc., Industry.*

Date.	Insured.	Unemployed.	Number Employed.
July, 1930 ..	102,620	8,783	93,837
1931 ..	108,340	16,057	92,283
1932 ..	117,490	10,310	107,180
1933 ..	125,570	15,843	109,727
1934 ..	133,280	10,260	123,020
1935 ..	142,200	11,511	130,689
1936 ..	151,830	8,736	143,094
1937 ..	177,670	6,653	171,017
1938 ..	170,820	13,461	165,359
1939 ..	185,290	8,301	176,989

The increase in the number en ployed has amounted to 88 per cent. since 1930 and has been even more rapid than in the heavy section of the industry. There was a sharp expansion in the number between 1936 and 1937, from 143,094 to 171,017, and although this was followed by a slight decline to 166,359 in 1938, probably due mainly to the depression in the radio industry in that year, there was a recovery in 1939 to the record figure of 176,989.

(i) *Insulated Wire and Cables.*—Most of the larger cable manufacturers experienced some decline in business in 1938 and the reduced level of activity continued in the early part of 1939. Towards the middle of the year, however, an improvement began, and this was intensified by heavy Government orders after the outbreak of war. The decline in the profits of some of the leading companies for 1938, after a period of unbroken prosperity extending over several years, caused a certain amount of anxiety regarding the future of the industry. It was pointed out that the virtual completion of the Grid was bound to affect demand, while, in addition, there was some evidence that the pace of the demand for electricity-consuming products was tending to slow up. Probably more important, however, was the effect of the growth of competition from firms outside the Cable Manufacturers' Association. At any given time the volume of business held by outside firms was not of prime importance, though the degree of support which such firms received from local authorities and consumers generally indicated a good deal of dissatisfaction with the price policy hitherto pursued by the C.M.A. The hint was taken by the larger manufacturers, however, and sundry price concessions were made. These reductions probably accounted for a considerable part of the decline in profits in 1938, though this was undoubtedly accentuated by a fall in demand.

Actually, competition from firms outside the C.M.A. has fallen into two categories. There can be no doubt that profit margins in the industry were on the high side and a number of independent manufacturers could and did sell at lower prices without having to resort to the manufacture of inferior products. On the other hand, as pointed out by the chairman of the General Cable Manufacturing Company, Limited, one of the leading independent producers, one or two independent companies had been pursuing a policy of uneconomic competition which could only have resulted in disorganising the whole industry. This type of competition reached its zenith in 1938 and, although it was not entirely absent in 1939, there was a material improvement in the position in that year, due to the elimination of one or two of the companies concerned. One of the plants closed down was the Kniveton Cable Works of Sterling Industries, Limited (formerly Ismay Industries, Limited).

On the whole, it would seem that the threat of serious outside competition has been of value in stressing the necessity of maintaining prices at the lowest possible level, consonant with the maintenance of the quality of output and a reasonable level of profit. With the present level of prices it seems unlikely that further new companies will attempt to enter the industry and the principal independent companies appear to appreciate the wisdom of refraining from serious price cutting.

International exports of insulated wire and cable are shown in Table II, on this page. There was very little change in 1939 in British exports, which were valued at 2,816,000*l.* in the first eight months of the year, compared with 2,907,000*l.* in the corresponding period of the previous year. The British share of total exports from the countries included in Table II also showed little change, and amounted to 38·6 per cent. in the first eight months of 1939, against 38·5 per cent. for the whole of 1938. The only change in the international situation was an increase in the Japanese share of total exports, at the expense of Belgium, Germany and the United States. Of the total British exports, those of submarine, and other, telegraph and telephone wires and cables declined between 1938 and 1939, the former from 150,000*l.* in the first eight months of 1938 to 86,000*l.* in 1939 and the latter from 615,000*l.* to 589,000*l.* Exports of rubber-insulated cables, on the other hand, rose from 912,000*l.* to 956,000*l.* In 1939, the principal markets for this category were Australia (296,000*l.*), India (167,000*l.*), and the Union of South Africa (165,000*l.*). Exports of cables with insulation other than rubber declined from 1,230,683*l.* to 1,185,030*l.*, the principal markets in this case being South Africa (301,859*l.*), Australia (230,994*l.*), and India (216,025*l.*).

The future outlook for British exports of insulated wire and cables is somewhat uncertain. This, however, is a field in which German exports are likely to be curtailed at a comparatively early date owing to the heavy consumption of copper involved in the manufacture, with the result that the demand for British cables should show a marked expansion. On the other hand, British manufacturers are heavily engaged on military orders, and the demand for copper is reaching such high levels that supplies may not be readily available to cover an increased export of cables. In normal times, the cable industry consumes over 40 per cent. of the total consumption of copper in this country. Nevertheless, as copper is produced on a large scale in the British Empire, as also are the other principal raw materials for cable manufacture, such as lead and rubber, increased cable exports represent one of the most satisfactory methods of improving the foreign trade balance and thus of helping to finance imports necessary for the prosecution of the war. In 1938, the principal markets for German submarine and underground cables were Holland (8,865 metric tons), Sweden (4,276 tons), Rumania (4,079 tons), Ireland (3,217 tons), South Africa (2,250 tons), India (1,907 tons), and the Argentine (1,917 tons). In the case of other insulated cables the principal markets were China (1,488 tons), Sweden (1,184 tons), and Holland (1,106 tons).

Table II.—Exports of Insulated Wire and Cable. (£000.)

——	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
United Kingdom	1,449	1,614	2,158	40·3	2,685	40·8	2,947	38·9	4,397	40·0	4,320	38·5	2,816	38·6
Germany ..	1,601	1,551	1,603	30·0	1,900	28·9	2,446	32·3	3,216	29·2	3,547	31·8	2,258	30·8
Japan ..	161	281	518	9·6	767	11·4	801	10·6	889	8·1	1,160	10·4	990	13·5
Belgium ..	436	405	457	8·6	517	7·8	565	7·4	1,339	12·2	1,093	9·8	581	7·9
United States	304	262	335	6·3	397	6·0	460	6·1	781	7·1	680	6·1	379	5·2
France ..	310	331	278	5·2	335	5·1	365	4·7	379	3·4	375	3·4	294	4·0
Total ..	7,261	4,444	5,349	100·0	6,601	100·0	7,584	100·0	10,991	100·0	11,175	100·0	7,318	100·0

Table III.—Exports of Wireless Apparatus (Including Valves). (£000.)

——	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
Netherlands	4,422	4,809	5,975	41·0	5,300	36·8	4,424	31·9	5,863	34·7	5,046	34·2	3,228	34·2
United States	3,799	3,823	4,931	33·8	5,230	36·5	5,689	41·0	6,493	38·3	4,724	31·9	2,862	30·3
Germany ..	2,998	2,103	2,104	14·4	2,215	15·5	2,266	16·3	2,733	16·2	3,042	20·6	2,081	22·0
United Kingdom	1,123	1,340	1,574	10·8	1,609	11·2	1,501	10·8	1,826	10·8	1,976	13·3	1,280*	13·5
Total ..	12,175	12,075	14,854	100·0	14,354	100·0	13,880	100·0	16,915	100·0	14,788	100·0	9,451	100·0

* United Kingdom figure for radio-gramophones (included in the total each year) is an estimate for 1939.

Table IV.—*Monthly Index of Cable-Traffic Activity.* (1929 = 100.)

	1932.	1933.	1934.	1935.	1936.	1937.	1938.	1939.
January ..	73·4	69·9	71·8	73·2	71·2	85·8	71·5	69·0
February ..	82·9	71·7	74·7	74·4	73·3	84·6	73·7	70·5
March ..	77·8	70·4	72·8	76·2	76·0	90·6	74·7	74·6
April ..	71·4	71·8	71·6	74·6	71·6	83·7	71·5	75·1
May	67·7	70·7	73·1	72·5	67·6	78·6	65·3	69·7
June ..	64·7	70·1	70·1	70·2	70·3	73·5	66·4	65·9
July	63·2	67·5	68·9	66·7	70·3	73·4	63·1	
August ..	69·6	85·9	70·7	67·1	69·1	73·0	60·2	
September ..	71·4	67·9	70·3	75·5	70·7	72·6	71·3	
October ..	73·2	72·1	73·6	78·8	75·9	76·5	88·7	
November ..	73·0	71·8	71·3	72·7	80·5	72·5	68·0	
December ..	78·8	76·7	80·7	80·1	96·4	82·5	77·1	

Source: Cables and Wireless, Limited.

(ii) *Wireless.*—For the greater part of 1939, manufacturers of wireless sets were suffering from the virtual saturation of the market, reached in 1937. This is not to say that demand was altogether unsatisfactory; although virtually confined to replacements, it was probably slightly higher than in the previous year. During 1938, owing to the recession in industrial activity generally and the higher level of unemployment, many prospective purchasers tended to delay replacement. With the improvement in the employment situation, this deferred replacement began to make itself felt in the early part of 1939, and demand received a further fillip from the outbreak of war as a result of the black-out, the desire to hear important war news without delay, and the curtailment of entertainment facilities.

Figures for the number of wireless licences current have not been published since the end of September, 1939, when the approximate total was 9,085,050. This compares with 8,908,900 at the end of 1938, showing an increase of 176,150 in nine months, or a monthly average of 19,570 against a figure of 27,420 for 1938 and of 43,268 for 1937. The effect of the war is shown by the fact that the increase in the month of September, 1939, was 41,323, very little below the monthly average for 1937. By no means the whole of this sharp increase, however, is attributable to war conditions, since, owing to the fact that the Radiolympia exhibition is held at the end of August, and that much more intensive use is made of wireless sets in the winter than in the summer, sales in the months of September to December are normally somewhat higher than the average for the year.

It is impossible to escape the conclusion, from these figures, that saturation point has now been reached. The total sales of wireless sets in 1935, the latest year for which this figure is available, amounted to 1,850,000, including radio-gramophones. Exports, exclusive of radio-gramophones, totalled 56,000, so that home sales may be estimated at about 1,790,000. In view of the fact that the annual increase in the number of wireless licences current has been declining since 1932, it is probable that production in the years subsequent to 1935 did not show any considerable increase. The average life of a wireless set is generally reckoned at between 6 and 8 years, so that, on a total number of sets in use of 9½ millions (allowing 500,000 for unlicensed sets and for cases where more than one set is run on one licence), the replacement demand may be expected to settle down between 1,200,000 and 1,600,000 annually. It is not to be expected that this level of replacement will be achieved immediately, because, six years ago, the number of sets in existence was only about 6 millions, giving a replacement demand at the present time of between 800,000 and 1,000,000. Actually, it was announced in January, 1940, that British manufacturers were planning to produce 900,000 sets for the domestic market and 200,000 for export, during 1940.

Under these conditions it is clear that, if the industry is to recover the prosperity of the years 1935 to 1937, a very marked expansion of exports must be achieved. In the first eight months of 1938, British exports of wireless sets, other than radio-gramophones, showed a small increase to 42,997, compared with 41,159 in the corresponding period of the previous year. Table III, opposite, shows, by value, the total exports of wireless apparatus, including valves, from the United Kingdom, Netherlands, the United States, and Germany. This shows that, between 1937 and 1938, British manufacturers increased their share of the total world trade and managed to hold this increased share in 1939. British exports, however, are still considerably below those of the other three countries shown.

At the 1939 Radiolympia, special attention was given to the development of export sales, and for the first time there was a special export section of the Exhibition. An extensive range of sets was shown, designed for particular countries and not available for the home market. On the outbreak of war, however, considerable anxiety arose on account of an announcement that the export of wireless valves and of permanent magnets was to be prohibited except under licence. The matter was taken up by the Radio Manufacturers Association, however, and it was explained that the prohibition did not apply to valves or magnets fitted as integral parts of wireless sets.

Although no figures are available, it is understood that the progress of exports since the outbreak of war has already been encouraging. Prospects of exports to the British Empire have been improved by the necessity for those countries to deal on a sterling basis and in some cases an import-licensing system has been imposed on foreign goods. It is also hoped that the war may make possible some relaxation of the imports of wireless sets into New Zealand, which, up to the beginning of 1939, was one of the largest markets for British sets. In the first quarter of 1939, however, imports into New Zealand from Great Britain were restricted to 25 per cent. of those for the same period in the previous year. It was little consolation to British manufacturers that imports of foreign sets were entirely prohibited. India was the second largest market in 1938, followed by South Africa, Eire and Australia. In India, British sets are subject to a duty of 40 per cent., which is, however, 10 per cent. lower than the duty on foreign sets.

The principal markets for German exports of wireless sets and parts have been Holland, Sweden, Finland, France and Brazil. It will not be particularly easy, however, to secure any of the trade which Germany may lose as a result of the blockade or of shortage of raw materials, owing to strong competition from Holland and the United States. Manufacturers in the former country appear to draw supplies of certain parts from Germany, and it might prove possible to supplant Germany in this trade.

The main points regarding the outlook in the home market have been covered already. Taking a longer view, it must be recognised, however, that any rapid development of television might considerably alter the position. During 1939, there was a strong demand for the extension of television services to parts of the country other than London, and, prior to the outbreak of the war, it seemed probable that a new transmitter would be set up in 1940, probably in the Midlands. The industry was particularly disappointed, therefore, when it was decided on the outbreak of war to suspend the television service completely in the interests of national safety.

A factor which may affect future home sales of wireless receivers is the extension of relay services, which may result in restricting sales of the lower-priced sets. There was at first a tendency to believe that the decision of the Post Office to develop broadcast relays over telephone wires would seriously affect wireless manufacturers. In point of fact, it is understood that this is not likely to be the case, since the relay of several programmes over one line requires a full set at the reception end, and the Post Office decision was reached after full consultation with the Radio Manufacturers' Association. Another development which is creating some anxiety is that of relaying programmes over electric power mains. This again requires a receiving set, but it is feared that the electricity supply companies might undertake the sale or even hire of the necessary equipment with serious repercussions on retailers of wireless sets.

(iii) *Telegraph and Telephone Apparatus.*—The year 1939 was again a prosperous one for suppliers of telegraph and telephone apparatus, though in export markets some ground was lost to German manufacturers. In this country, capital expenditure on the telephone service in the year 1939-40 was scheduled to amount to 22,300,000*l.* Even after the extension represented by this expenditure, the prospects of the industry appeared very satisfactory, since this country is still behind several others, notably the United States and Denmark, in "telephone consciousness." It was expected that some curtailment in future development might result from the recommendation of the Select Committee on Estimates that drastic reductions should be made wherever practicable in Post Office expenditure; but the Post Office announced that its policy would not be directed to curtailing in any way the services at present available to the public. In pursuit of economy, steps were taken to review the working of the bulk agreement between the Post Office and the principal telephone manufacturers. This bulk agreement was concluded several years ago to secure to the Post Office the benefits of standardisation of equipment, planned production and the pooling of patents. A number of price adjustments have been made under the agreement from time to time.

The outlook has been altered, of course, by the outbreak of war, and it is to be expected that future development will be somewhat restricted on this account. On the other hand, a fair level of manufacturing activity is assured in the provision of reserve stocks of equipment, and problems of developing emergency communications in face of large-scale evacuation of businesses and of Government departments have resulted in a high level of activity up to the present. With regard to general development, the suspension on the outbreak of war of cheap night telephone facilities was undoubtedly likely to retard progress and the decision to reintroduce these facilities from February 12, 1940, therefore, is particularly welcome.

Further progress was made during 1939 in the development of the 12-channel carrier telephone system. Some 560 miles of cable were installed during the year, and a further 700 miles were on order or under construction. In addition, some 2,500 miles of loaded trunk cables were installed or in course of manufacture. With regard to overseas communications, traffic was apparently running at

TABLE V.—EXPORTS OF TELEGRAPH AND TELEPHONE APPARATUS. (£000.)

—	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
United Kingdom	670	1,074	1,108	34·0	1,722	38·8	1,765	39·7	2,112	37·6	2,917	41·9	1,684	36·7
Germany ..	1,420	991	984	30·1	1,150	26·0	1,251	28·1	1,479	26·4	1,630	23·5	1,250	27·1
Belgium ..	593	348	411	12·6	555	12·5	540	12·1	754	13·4	951	13·7	505	10·9
United States	284	228	290	8·9	430	9·7	493	11·1	765	13·7	834	11·9	537	11·7
France ..	123	149	155	4·8	320	7·2	63	1·4	114	2·0	85	1·2	81	1·8
Sweden ..	377	242	314	9·6	258	5·8	338	7·6	386	6·9	545	7·8	544	11·8
Total ..	3,467	3,042	3,262	100·0	4,435	100·0	4,450	100·0	5,610	100·0	6,962	100·0	4,601	100·0

TABLE VI.—EXPORTS OF INCANDESCENT LAMP BULBS. (£000.)

—	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
Netherlands*	861	1,034	894	25·6	812	23·8	718	20·2	821	21·0	713	21·3	452	21·7
Germany ..	788	774	745	21·4	790	23·2	741	20·9	887	22·7	} 849	25·4	507	24·2
Austria† ..	191	200	188	5·4	202	5·9	186	5·2	189	4·8				
United Kingdom	375	427	508	14·6	571	16·7	596	16·8	652	16·7	594	17·8	394	18·8
Japan ..	819	620	529	15·2	448	13·2	575	16·2	621	15·9	397	11·9	278	13·3
Hungary‡ ..	281	337	428	12·3	370	10·8	467	13·2	425	10·9	513	15·4	272	13·0
United States	164	149	193	5·5	217	6·4	206	7·5	313	8·0	272	8·2	188	9·0
Total ..	3,479	3,541	3,485	100·0	3,410	100·0	3,549	100·0	3,908	100·0	3,338	100·0	2,091	100·0

* Metal filament only.
† Includes also other mounted glasses for electric luminous effects.
‡ Hungarian exports are converted into sterling at the free rate of exchange.

rather a lower level in the early months of 1939 than in the corresponding period of the previous year. The monthly index of cable-traffic activity, however, shown in Table IV, on page 218, has not been published since June. The reason for the suspension was given by the chairman of Cables and Wireless (Holding), Limited, as the fact that the index was interpreted in widely diverse ways and did not now give a true account of the position. It was stated that it indicated only a section of the company's receipts and did not take into account any economies or reduced expenditure.

A notable development during the year was the introduction, from May 1, of a new class of inter-Empire telegram for social use at a cheap rate of 5*s*. for 12 words. Following their offer to create a system of radio-telegraph and radio-telephone communications throughout the Colonial Empire without cost to the administrations, Cables and Wireless, Limited, took active steps to install the necessary apparatus in several countries. A radio-telephone service was established between Canada and Newfoundland in January, 1939, and this enabled a similar service to be conducted between Newfoundland and Great Britain. A radio station at Athens, for communications with London, Paris, Rome and Cairo, was scheduled to be brought into service by the end of the year.

British exports of telegraph and telephone apparatus declined from 1,948,258*l*. in the first eight months of 1938 to 1,683,639*l*. in the corresponding period of 1939. As shown in Table V, on page 219, this resulted in a fall in the British share of total exports from the principal manufacturing countries from 41·9 per cent. in 1938 to 36·7 per cent. in the first eight months of 1939. This fall was counterbalanced by increased exports from Germany. The principal British markets in 1939 were Australia (431,112*l*.), South Africa (264,716*l*.) and the Argentine (139,413*l*.). The principal German markets were Holland, Italy, China, Greece, Yugoslavia and Finland.

(iv) *Incandescent Lamps.*—The year 1939 has seen further developments in the competition between members of the Electric Lamp Manufacturers' Association and outside interests. Not only were there renewed polemics over the patents covering "coiled-coil" lamps, but, in addition, the number of manufacturers was further extended. The Scottish Co-operative Wholesale Society began production at its new factory at Shieldhall, near Glasgow, in August. The new company, which is run jointly by the Scottish and Swedish Co-operative Societies, announced that its lamps would be sold on Association terms, but special discounts would be allowed to co-operative retail establishments. In July, Messrs. E. K. Cole, Limited, wireless-set manufacturers, announced their intention to undertake the production of lamps. For some time this company had been conducting research and experimental work on lamp production, and it was stated that lamps would be on sale by the autumn.

The black-out has created a number of problems for lamp manufacturers. The demand for street lamps has virtually ceased, though research has been proceeding on the development of methods of street lighting which shall be invisible from the air. The demand for cycle and battery lamps has been very great, however, and in some cases difficulty has been experienced in maintaining adequate supplies. British exports of incandescent-lamp bulbs were valued at 394,000*l*. in the first eight months of 1939, against 594,000*l*. for the whole of 1938, the British share of the total exports from the countries shown in Table VI, on page 219, amounting to 18·8 per cent. in 1939, against 17·8 per cent. in the previous year.

(v) *Batteries and Accumulators.*—The past year has been an active one for manufacturers of batteries and accumulators. Even before the outbreak of war, sales, on the whole, were running at a higher level than in the previous year, though in the case of dry batteries it must be remembered that sales in 1938 were not particularly satisfactory. Prices generally continued at a low level, but the policy of ruthlessly meeting cut-price competition, adopted by the members of the Association of Radio Battery Manufacturers, appears to have been completely successful in preventing any decline in the volume of their sales, and no new threat by outside firms was made during 1939.

For some years sales of dry batteries have been declining owing to the growth in popularity of all-mains wireless sets, though there are reasons for believing that the decline was by no means as large as might have been expected. This position was quickly reversed on the outbreak of war, and an acute shortage of torch batteries developed. The demand naturally resulting from the black-out was accentuated by the regulation making rear lamps compulsory on bicycles. At the same time, the export demand increased substantially. Owing to the seasonal nature of the demand for batteries, manufacturers were not justified in extending their plant on the necessary scale, though some extensions have been made. Output was increased, however, by two-shift working. After several reported cases of profiteering in torch-battery prices, the principal manufacturers fixed maximum retail prices for these and cycle-lamp batteries. Recently some batteries have been imported, mainly from Belgium, but it has been reported that the supply is not likely to overtake the demand before the spring of the present year.

With regard to accumulators, there has been a good demand for armament purposes; for submarines, in particular, the requirements are large. In addition, there has been steady progress in the provision of emergency lighting sets in hospitals, hotels, cinemas and theatres. Another important market is in electric vehicles, for which there has been an increasing demand, as discussed in the previous article in this series.

British exports of dry batteries were valued at 412,000*l*. in the first eight months of 1939, or 48·5 per cent. of the total exports from the countries shown in the accompanying Table VII, against 538,000*l*., or 51·9 per cent., for the whole of 1938. In the case of accumulators, an alteration has been made in the basis of the British trade returns and the figures for 1939 are not really comparable with those for the previous year.

(vi) *Meters and Instruments.*—British exports of meters and instruments were valued at 348,000*l*. in the first eight months of 1939, or 14·3 per cent. of the total exports from the countries shown in Table VIII, herewith, compared with 496,000*l*. (also 14·3 per cent.) for the whole of 1938.

TABLE VII.—Exports of Batteries and Accumulators. (£000.)

——	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
Batteries only.														
United States	662	481	476	58·0	541	61·2	620	61·7	757	60·9	538	51·9	412	48·5
United Kingdom	179	205	192	23·4	177	20·1	183	18·2	192	15·5	163	15·7	100	11·7
Germany ..	263	179	151	18·6	167	18·7	202	20·1	293	23·6	336	32·4	339	39·8
Total Batteries ..	1,104	865	819	100·0	885	100·0	1,005	100·0	1,242	100·0	1,037	100·0	851	100·0
Accumulators only.														
United Kingdom	463	517	525	44·2	505	40·7	565	43·2	597	37·7	584	40·8	175*	23·2
United States	304	234	315	26·6	342	27·6	365	27·9	571	36·1	449	31·4	319	42·3
Germany ..	500	242	189	16·0	243	19·6	257	19·7	293	18·5	268	18·7	161	21·4
France ..	179	188	156	13·2	150	12·1	120	9·2	122	7·7	130	9·1	99	13·1
Total Accumulators ..	1,446	1,181	1,185	100·0	1,240	100·0	1,307	100·0	1,583	100·0	1,431	100·0	754	100·0

* Not completely comparable with figures for previous years.

TABLE VIII.—Exports of Meters and Instruments. (£000.)

——	1932.	1933.	1934.	Per cent.	1935.	Per cent.	1936.	Per cent.	1937.	Per cent.	1938.	Per cent.	1939.	Per cent.
Germany ..	1,762	1,413	1,397	50·5	1,533	50·4	1,722	53·6	1,802	51·5	1,731	49·8	1,215	50·0
Switzerland ..	609	708	771	27·8	734	24·3	627	19·5	620	17·7	628	18·0	397	16·3
United States	394	248	297	10·8	391	12·9	443	13·8	637	18·2	623	17·9	475	19·4
United Kingdom	287	259	302	10·9	376	12·4	423	13·1	438	12·6	496	14·3	348	14·3
Total ..	3,052	2,628	2,767	100·0	3,034	100·0	3,215	100·0	3,497	100·0	3,478	100·0	2,435	100·0

ELECTROLIMIT GAUGES.

At the present time, even more than under normal conditions, the rapid and accurate gauging of mass-produced components by the employment of only unskilled labour is a matter of importance in the manufacturing industries. The instruments illustrated in Figs. 1 to 4, on the opposite page, and known as Electrolimit gauges, are of considerable interest, therefore, since they enable the inspection of components to be reduced to a simple routine. With their aid, parts can be tested for size and, if required, graded into accurately matched groups, with great rapidity, and with no more skill than is needed to observe the position of a pointer on a scale. Introduced by Messrs. The Pratt and Whitney Company, of Hartford, Conn., U.S.A., these gauges are now made in this country, under licence, by Messrs. Taylor, Taylor and Hobson, Limited, Stoughton-street Works, Leicester, who supply them in various types and sizes to cover a wide range of requirements.

A photograph of the Electrolimit gauge for external work is reproduced in Fig. 1, opposite. The instrument comprises a well-ribbed cast-iron base into which a chromium-plated steel tubular pillar is fitted. The pillar carries a bracket, on which is mounted an electrically-operated measuring head that can be moved up and down the pillar by means of a screw operated by a handwheel and engaging with a nut fitted in the bracket. When set in the required position, the bracket can be clamped to the pillar by means of a pad bolt.

The object to be gauged is placed on a movable anvil of hardened tool steel, which fits into the base, as shown, and is reversible to bring either of two surfaces into use. The anvil is chromium-plated and is optically flat, so that slip gauges can be wrung on to it. It should be noted, however, that one of the surfaces is serrated, the object of the serrations being to prevent any small metallic particles or other foreign bodies from interfering with the gauging operations. A longitudinal section through the electrically-operated measuring head is given in Fig. 3, and this, with the aid of the electrical wiring diagram, Fig. 4, will enable the principles upon which it depends for its action to be followed.

It should be first explained that the lower end of the plunger *a*, in which a diamond is mounted, is located at an accurately known distance above the anvil by means of an end gauge, or a combination of slip gauges, when setting up the instrument. The upper end of the plunger is held in contact with a steel lever armature *b*, the contact being maintained by springs and the armature being mounted on a flat steel strip at one end, so that it is capable of tilting. The free end of the armature is located between two inductance coils, *c* and *d*, and it will be clear that with this arrangement any vertical movement of the plunger will increase the air gap between the armature and one of the coils, and diminish the other air gap. The coils form two of the arms of an inductance bridge, shown on the left in Fig. 4, the other two arms including variable inductances used for varying the magnification and adjusting the zero, respectively. Alternating current from the mains is supplied to the bridge circuit through a voltage regulator and transformer, and a sensitive microammeter of the moving-coil type is connected across the bridge to measure the out-of-balance current which flows as a result of the movement of the arma-

EXTERNAL AND INTERNAL ELECTROLIMIT GAUGES.

MESSRS. TAYLOR, TAYLOR AND HOBSON, LIMITED, LEICESTER.

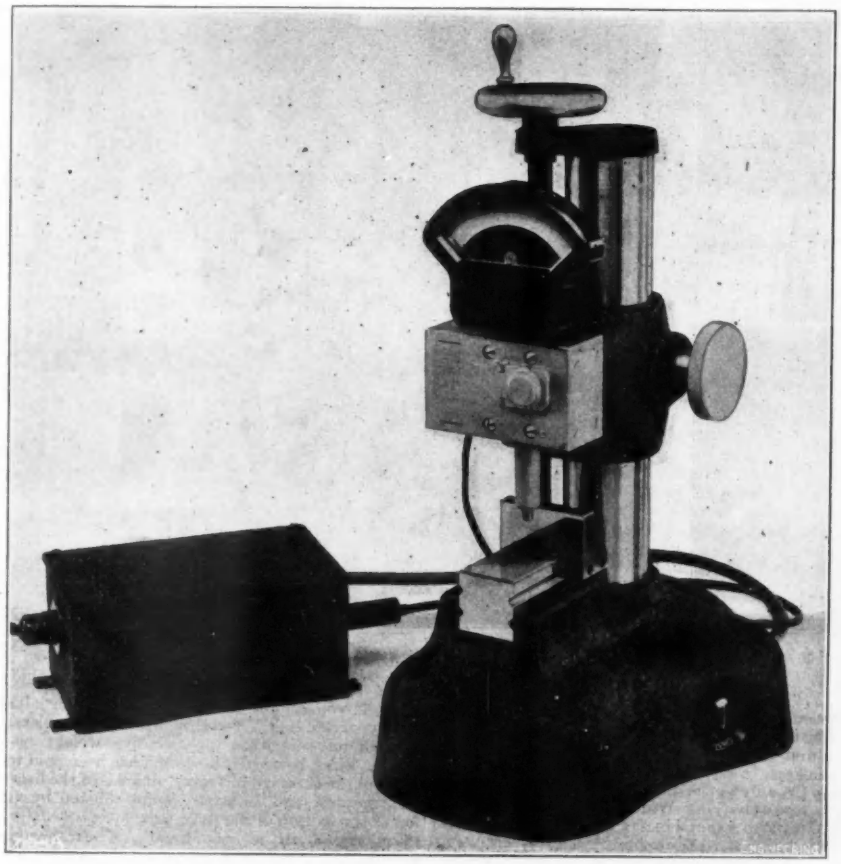


FIG. 1. EXTERNAL-TYPE GAUGE AND POWER UNIT.

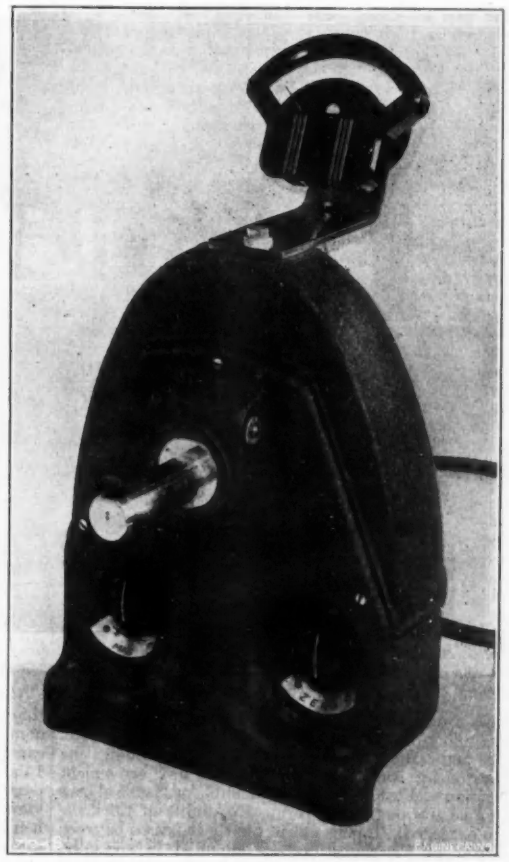
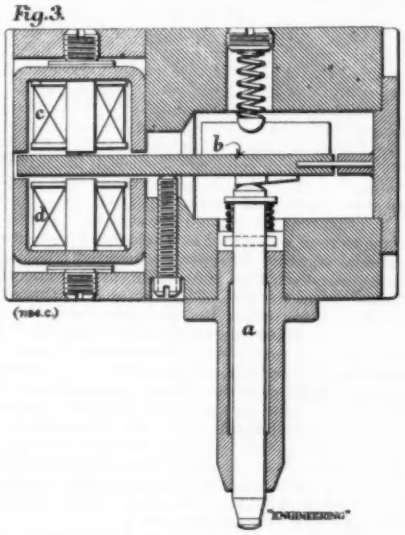
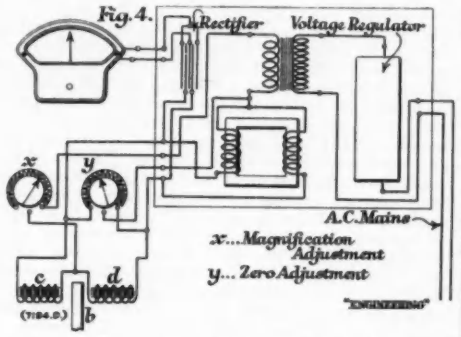


FIG. 2. INTERNAL-TYPE GAUGE.





ture *b* and is proportional to that movement. To render possible the use of an indicating instrument of the moving-coil type, the out-of-balance current must, of course, be passed through a rectifier.

In the gauge illustrated in Fig. 1, the maximum distance between the diamond gauging point and the working surface of the anvil is 4½ in., and the distance between the axis of the plunger and the periphery of the vertical pillar is 2¼ in. A larger instrument, in which these dimensions are 10¾ in. and 4 in., respectively, is also available. Two forms of micro-ammeter can be supplied for use with either instrument, one having a 3¼-in. scale and the other a 4½-in. scale; and the graduations, which are not visible in the illustrations, may be either progressive from zero to a maximum, or of the central-zero type, giving plus or minus readings. A special feature of the instrument is that the magnification can be adjusted, this being done by means of the knurled knob shown on the right-hand side of the base in Fig. 1, and the range of adjustment is such that the full-scale deflection of the indicating instrument may be made to correspond to a movement of the gauging point of from 0·00025 in. to 0·004 in.; a suitable slip gauge is used for checking the magnification. With the former magnification and using a 4½-in. scale indicating instrument, errors of a millionth of an inch can be measured without great difficulty. The zero adjustment, which must be made when the gauging point is brought into contact with the slip gauges or end gauge used in setting up the instrument, is effected by turning a knurled-head screw located under a small cover plate on the front of the measuring head, and visible in Fig. 1.

The instrument illustrated in Fig. 1 is fitted with an adjustable back stop of hardened chromium-plated steel, the back stop being secured to the anvil by set screws. The back stop is not usually supplied with the larger instrument, but both sizes can be fitted with an internal gauging attachment with which holes up to 3 in. in diameter can be inspected for size and circularity. The instrument illustrated in Fig. 2, however is specially designed for internal gauging. It is of the bench type, and is made in two sizes for gauging holes ranging from ½ in. to 1½ in. and from 1½ in. to 3 in. in diameter, respectively. Portable instruments are made for holes ranging from ½ in. to 1½ in. and from 1½ in. to 2 in. in diameter, and also for gauging cylinder bores from 2 in. to 3 in., and from 3 in. upwards, in diameter.

In principle, the internal Electrolimit gauges are similar to the external gauges previously described. In the bench-type internal gauge, however, the base which supports the horizontal gauging spindle is of cast iron and has three feet provided with holes for fastening the instrument to a bench. The magnification and zero controls are housed in the base and the indicating micro-ammeter is mounted on the dome cover, as shown in Fig. 2. The gauging spindle consists of a cylindrical body formed integrally with a flanged shank for fitting it to the base and has a diameter slightly smaller than the minimum diameter of the hole it will gauge, to provide the necessary clearance. Chordal or radial relief is given along the whole length of the spindle by two line contacts in the form of tungsten-carbide strips let into the spindle. These two strips, together with a diamond gauging point, give a triagonal contact between the spindle and the hole being gauged. To ensure the correct positioning of the spindle in the hole during the gauging operation, a pressure shoe is placed underneath the strip contacts and adjacent to the gauging point. The latter is a rounded diamond, formed with a radius suitable for the holes to be measured. The length of the gauging spindle is usually three times its diameter. A range of holes may be gauged with one base unit and a number of spindles, which can be changed from one size to another in a few minutes. Standard pressure shoes are used on all spindles of ½ in. diameter and over, but on spindles for smaller holes a special type of tension shoe can be supplied. The magnification obtainable is the same as with the internal gauges, but the zero setting and magnification adjustment is done by means of suitable ring gauges.

In conclusion, it may be mentioned that an Electrolimit gauge of the external type, and operating on the principle explained above, is made for continuously

ROLLING STOCK FOR THE LIVERPOOL AND SOUTHPORT LINE, L.M.S.R.

MR. W. A. STANIER, M.I.MECH.E., CHIEF MECHANICAL ENGINEER.

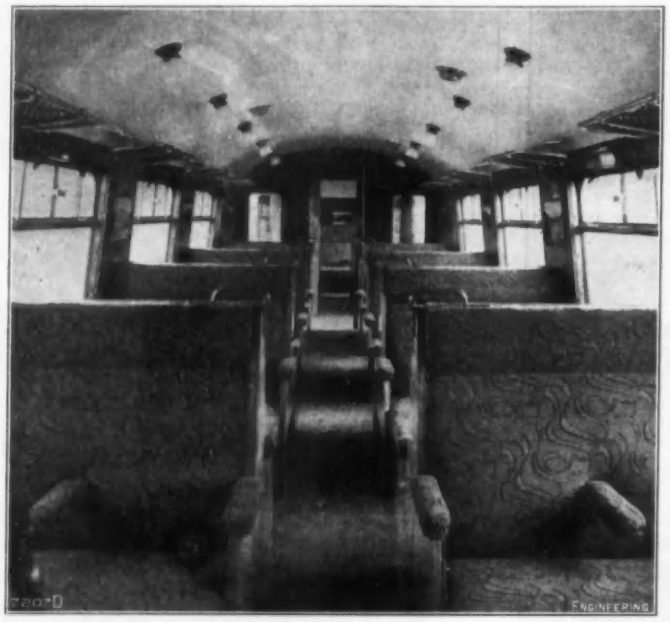


FIG. 1. FIRST-CLASS COMPARTMENT.

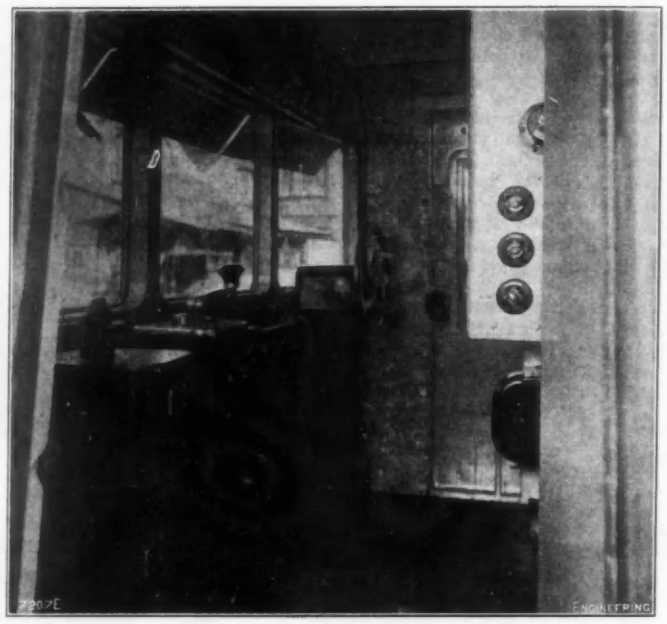


FIG. 2. DRIVER'S COMPARTMENT.

measuring the thickness of strip or sheet as it leaves the rolling mill at speeds up to 1,200 ft. per minute. The indications are given on a separate indicating instrument, which can be located in any convenient position and can be fitted with audible or visible alarms to give warning if the permissible limits of thickness are exceeded. In this gauge the sheet passes between a pair of Vee-shaped rollers mounted in specially-selected ball bearings and the relative movement of the axes of these rollers, electrically magnified in a manner similar to that described above, is used to obtain a continuous indication of the thickness variations.

NEW ROLLING STOCK FOR THE LIVERPOOL AND SOUTHPORT LINE, L.M.S.R.

IN ENGINEERING of February 16 was printed, somewhat abridged, a paper on "Lightweight Passenger Rolling Stock," prepared by Mr. W. A. Stanier, chief mechanical engineer of the London Midland and Scottish Railway, for delivery at the intended summer meeting in New York of the Institution of Mechanical Engineers and the American Society of Mechanical Engineers. Owing to the outbreak of war, this meeting was cancelled—or, in the official phrase, "postponed"—and the publication of the paper was delayed in consequence. Thus, we are in a position to supplement the paper, which described in detail the constructional processes adopted in the building of typical cars for service on the company's Liverpool and Southport line, by the following description of the complete trains.

The new rolling stock comprises 34 three-car units and 25 two-car units. Each three-car unit consists of a motor car with third-class accommodation, a third-class trailer car, and a composite trailer car with a driving compartment; and each two-car unit comprises a motor car (third class) and a non-driving trailer car. Sixteen of the two-car units have third-class trailer cars, and the remaining nine, composite. It will be seen that the two-car and three-car units can be used in sets, making up three-, four-, five-, or six-car trains, according to requirements. The overall length of a three-car unit is 209 ft. 2¼ in., and of a two-car unit 138 ft. 11¾ in. All the vehicles measure 49 ft. between the bogie centres, and all the bogies have a uniform wheelbase of 8 ft. 6 in. The overall length and width of the bodies are 66 ft. 6 in. and 9 ft. 3 in., respectively, and the height above rail level is 11 ft. 5 in. The motor cars have an unladen weight of 40 tons 10 cwt., the driving trailer cars 25 tons 1 cwt., and the non-driving trailers 23 tons 4 cwt. Seating accommodation is provided for 25 non-smokers and 63 smokers in each motor car. There is a guard's compartment, which can also be used for luggage. The non-driving trailer thirds have 102 seats. The composite cars have first-class accommodation for 38 smokers and 15 non-smokers, in addition to seats for 29 third-class passengers (25 only in the driving trailers). An interior view of a first-class compartment is given in Fig. 1, herewith, and Fig. 2 shows one of the driving compartments. Figs. 3 and 4, on the opposite page, respectively, show the under-frame arrangement of one of the motor cars, and a traction motor. A complete three-car unit is illustrated in Fig. 5, on page 226, and Figs. 6 and 7, on the same page, are comparative views of the trailing and driving bogies.

Each motor car has four axle-hung motors, rated at 235 h.p. for one hour or 184 h.p. in continuous running, at 580 volts. In the design of the motors, particular attention has been given to weight reduction, with the result that the weight per motor, complete with gear-case, gearwheel and pinion, is almost exactly 2 tons—actually, 4,484 lb. The motors are self-ventilating, and draw a supply of clean air from the top of the coach body, through ducts and flexible bellows. The armatures are carried in roller bearings. The power available is sufficient to give a fully-loaded 5-car train an initial acceleration of 1·6 m.p.h. per second, or a 6-car train 1·4 m.p.h. per second. Stopping trains will be able to maintain a schedule speed of about 30 m.p.h., with stations about 1¼ miles apart, and an allowance of 20 seconds per stop. For express services, the trains have a maximum speed in excess of 70 m.p.h.

There are two separate control equipments for each motor car, each controlling a pair of motors. Each equipment consists of 19 electro-pneumatic contactors, two having extended arc chutes and acting as line switches. Power is taken from a 'bus line fed by third-rail collector shoes on the motor coaches and driving trailers. One bogie only on the driving trailer cars is fitted with shoe beams, the other being the same as those fitted to the non-driving trailers. The control gear follows standard lines, in that it gives automatic acceleration to the train under the control of a current-limit relay. All the main parts of the equipment are carried beneath the coach, as shown in Fig. 3. The electro-pneumatic contactors for each pair of motors are carried in two cases and the electro-pneumatic reverser in a third.

A feature in the design is that both the main contacts and the interlock contacts are at the front of the contactor. A lever enables the magnet valve to be operated from the front, so that all inspection can be carried out from one side. All the main cases are so mounted on the underframe that they can be quickly removed from the coach by sliding out laterally. A spare set can then be substituted and the time the coach has to be out of service is reduced to a minimum. The low-tension supply for the control circuits is provided by a 52-volt motor-generator set and an alkaline battery of 36 cells. To obtain smooth acceleration, and full advantage of the adhesive weight on the motored axles, particular attention has been paid to the design of the current-limit relay, which is of the balanced armature type and, therefore, is not affected by vibration or the motion of the train.

Compressed air for the brakes, electro-pneumatic control and air-operated doors, is provided by a two-cylinder motor-driven air compressor taking current at 600 volts. This motor is controlled in the ordinary way by a compressor-governor, a synchronising wire being used to ensure that the compressors of a train operate simultaneously. One compressor is fitted to each motor car. Current for coach lighting is supplied through an electromagnetic contactor controlled by a set-and-trip switch in the guard's van. The coach heaters are also supplied at 600 volts. The heating contactor is controlled by a thermostat.

As the construction of the coach frames and bodies was described in considerable detail in Mr. W. A. Stanier's paper, to which reference has been made, the full description need not be repeated. It is sufficient to mention that the whole body structure, from underframe to roof, is designed as a structural unit, in which the sides and roof form a deep inverted truss, with a consequent saving in the weight of the underframe members. In the case of the motor cars, this method of construction offers the particular advantage that there are no trusses on the solebars below underframe level, so that more space is available for electrical equipment. The bodies are of steel, and extensive use has been made of arc-welding, all the underframe and body-frame members being connected by this means. Electric spot-welding has been introduced, for the first time on the L.M.S. Railway, for the attachment of panels to the body framing, and for similar purposes elsewhere. The interior partitions and screens are fabricated from light pressed-steel framing, arc-welded, and covered with steel sheet. Partitions which extend from side to side of the body are riveted. The spaces left between the interior surfaces of the body side and the roof panels are separately ventilated, to prevent corrosion.

The motor bogies, each accommodating two motors, are fabricated by arc-welding from high-tensile structural steel and are of the plate-frame type. The wheels are 3 ft. diameter, and the axle ends are mounted in Timken tapered-roller bearings. The axleboxes and axleguards have liners of manganese steel. The trailer and driving-trailer cars are mounted on bogies fabricated by arc-welding from mild-steel members, mainly rolled sections. The general design of the bogie follows customary practice. The wheels are 3 ft. diameter, and set at 8 ft. 6 in. wheelbase, as in the motor bogies. Skefko roller-bearing axleboxes are provided, some being of the double-bearing double-row self-aligning

LIGHT-WEIGHT ROLLING STOCK, L.M.S.R.

MR. W. A. STANIER, M.I.MECH.E., CHIEF MECHANICAL ENGINEER.

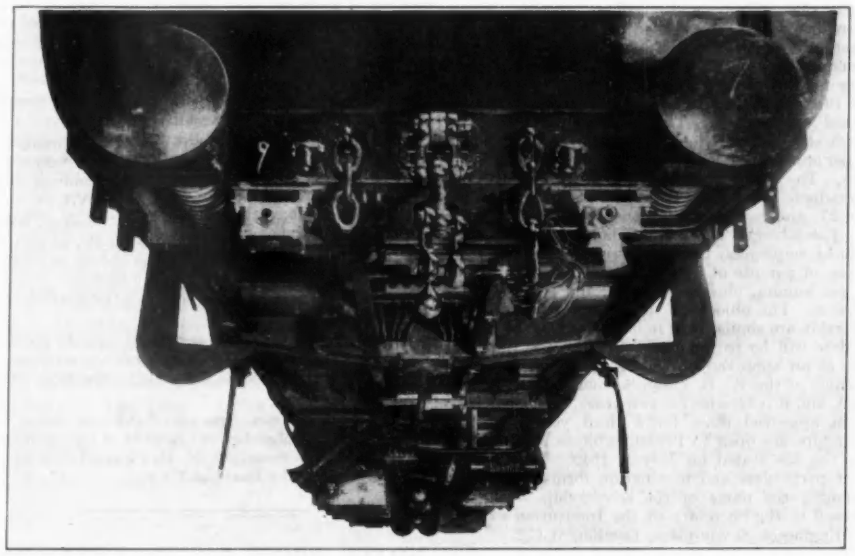


FIG. 3. UNDERFRAME EQUIPMENT OF MOTOR CAR.

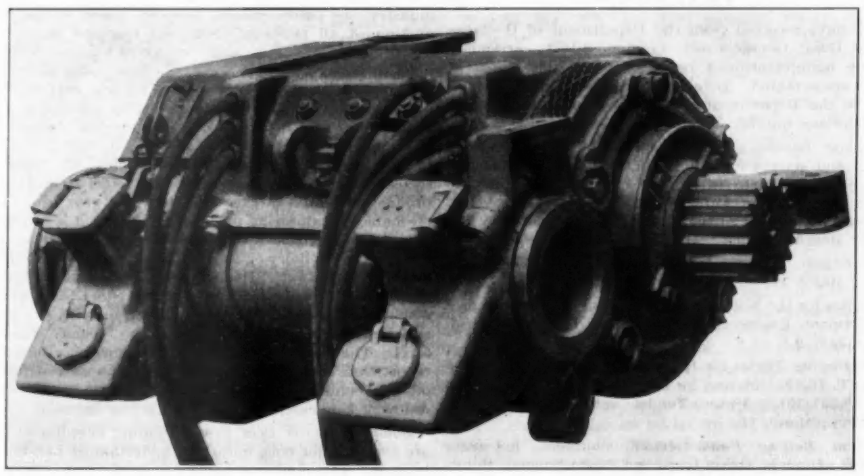


FIG. 4. TRACTION MOTOR.

type, while others have parallel rollers and the end thrust of the axle is taken on a bronze pad mounted on the axlebox end cover. All the boxes are oil-lubricated.

The buffing and drawgear follow the company's standard practice. Side buffers are provided, and screw couplings to all cars, at both close-coupled and loose-coupled ends. The only departure from standard practice is in the point of draw, which in this stock is just behind the headstock (strengthened for the purpose), instead of at the main transomes over the bogie centres, as is more usual. Westinghouse electro-pneumatic brakes are fitted. The driver is provided with a self-lapping type of brake controller and a gauge is mounted in each cab, indicating the pressure in the brake cylinder of the car in which it is situated. Cast-iron blocks are used on the motor bogies, and Ferodo blocks on the trailer bogies. Provision is made, however, for readily altering the leverage of the brake rigging on all cars if it is desired to change from cast-iron to Ferodo blocks, or vice versa.

Lighting is by means of 60-watt lamps, fitted five in series, and taking current from the 600-volt supply. White opal glass reflectors shade and reflect the light. The fittings are moulded in black Bakelite and are attached directly to the conduit boxes. As can be seen from Fig. 5, four headlights are provided for route-marking purposes, as well as the destination indicator recessed into the face of the driving compartment. The headlights can be individually masked by turning the reflector through 180 deg. by means of a handle within the cab.

Access to the passenger compartments is by doorways 3 ft. 9 in. wide, closed by double sliding doors, pneumatically operated by the guard. The guard can also release the multiple control, so as to enable a passenger to operate a single door by means of the push-buttons within and outside of the doorway. The opening and closing of each door operates an interlock switch which prevents the guard from sounding the driver's signal bell until all doors are closed.

The interior finish of the third-class compartments is plywood veneer, and the seat ends are laminated blockboard, veneered to match. The transverse seats are designed to seat three persons on one side of the gangway, and two on the other, and are upholstered in green uncut moquette. The seat frames are fabricated by welding from sheet-steel pressings. The floors are covered with linoleum laid on felt and cork, which is supported on galvanised-steel sheeting, welded to the underframe. The first-class compartments have arm rests to the seats, which are covered in fawn and brown uncut moquette, and a carpet is laid over the linoleum. The body side finish in the first-class accommodation is in betula veneered plywood. The windows throughout have sliding-light ventilators in the upper half. The drivers' cabs are not panelled inside, but are sprayed with asbestos by the Roberts' process, as a protection against excessive heat.

The new trains are being constructed at the Derby carriage and wagon works of the London Midland and Scottish Railway, to the designs of Mr. W. A. Stanier, and the electrical equipment, for which the contractors are Messrs. The English Electric Company, Limited, is to the specification and requirements of Mr. C. E. Fairburn, deputy chief mechanical engineer and chief electrical engineer.

THERMOSTATIC BIMETALS.*

By S. G. ESKIN and J. R. FRITZE.

(*Concluded from page* 213.)

Materials for High-Expansion Side.—It has been pointed out that commercially useful bimetals must consist of two metals having widely different coefficients of thermal expansion. In the previous section, the properties of low-expansion alloys have been described in detail. Materials for the high-expansion side, in addition to having a high coefficient of expansion, should have good brazing or welding properties, should develop high elastic properties as a result of cold-working, and should have high heat-resisting properties. Initially, brass used in combination with Invar resulted in a satisfactory bimetal for low-temperature applications up to approximately 300 deg. F. Further development led to the adoption of Monel for high-temperature bimetals, but the deflection constant when using Monel was rather low. To meet the requirements for high-temperature high-deflection bimetals of good constancy, various nickel-chromium alloys have been adopted for the high-expansion side. Representative analyses contained from 18 per cent. to 27 per cent. nickel, and from 3 per cent. to 11 per cent. chromium. Developments in high-temperature bimetals have been mainly in connection with the high-expansion side.

Stresses in Thermostatic Bimetals.—Bimetals free to deflect upon heating are subjected to internal stresses which at high temperatures may assume large values. If, in addition to internal stresses, bimetals are subject to stresses due to restraints, loads, etc., their performance may be critically affected if these stresses exceed the elastic limit of the material at high temperatures. Thus, it is necessary to evaluate stresses for applications involving high temperatures and loadings or restraints. Stresses due to external forces will vary, depending upon the application.

The primary function of thermostatic bimetals is to produce a deflection or a rotation when heated. In many applications, such as thermometers, the bimetal does not have to do any work, except that of moving an indicating pointer the bearings of which may have some friction. But there are other numerous applications where the bimetal is called on to do considerable work, such as lifting parts of mechanisms or overcoming stored energy in springs or magnetic systems to obtain snap action. In the case of those applications where the function of the bimetal is mainly to provide an indication of the temperature change, the deflection constant has to be considered. On the other hand, in cases where the bimetal is expected to do work, the force constant is of importance and has to be investigated to obtain a design of maximum efficiency.

In order to prevent changes in calibration of devices using bimetals upon initial heating, it is necessary to anneal the bimetal carefully. During the rolling operation stresses are set up which can be relieved by a proper annealing procedure. High-temperature thermostatic metals should be annealed by, for example, heating at 600 deg. F. for 1 hour if the material is to be used below 550 deg. F. In cases where the bimetals are to be used above 550 deg. F., annealing should be done at a temperature 50 deg. higher than the maximum temperature encountered in service. Low-temperature bimetals should be annealed at 350 deg. F.

Physical Properties of Bimetals.—In many applications the actuating bimetallic element is used in a manner similar to that of a spring; it is subjected to large deflections or rotations. It is expected, and usually it is essential, that the element should return to its initial position upon the removal of the restraining forces. The design of bimetallic elements where large deflections occur and permanency of calibration is necessary requires the knowledge of the stresses involved and the tensile properties of the material. The authors were unable to find in the available literature on thermostatic bimetals any data on the tensile properties of bimetals. Neither have the manufacturers of bimetals published information regarding the tensile properties of their products. In some cases, the moduli of elasticity have been determined and given in the catalogues.

One of the present authors, during a study of bimetals eleven years ago, measured the tensile strength and the elastic limit of metals available at that time. The results of these measurements are given in Table II, on page 224. The first four materials are as supplied by the H. A. Wilson Company, and the last two by the W. M. Chace Company. Bimetals available at present probably have higher tensile properties than those shown. With the exception of the brass-Invar type of bimetals, all other

* Paper presented at the Annual Meeting of the American Society of Mechanical Engineers, held at Philadelphia, U.S.A., from December 4 to 8, 1939. Abridged.

bimetals can be subjected to tensile stresses of the order of 31 tons per square inch at room temperatures. Manufacturers generally recommend stresses not exceeding 13·4 tons per square inch, which value

TABLE II.—*Tensile Properties of Thermostatic Metals.*

Metal and Treatment.	Tensile Strength.	Elastic Limit.	Elongation on 8 in.
	Tons per sq. in.	Tons per sq. in.	Per cent.
Wilson standard, as rolled ..	38·4	33·5	5·0
Wilson standard, annealed at 350 deg. F.	38·4	33·5	11·1
Wilson high-temperature con tant, as rolled ..	49·1	42·4	3·5
Wilson high-temperature constant, annealed at 750 deg. F.	49·1	38·1	12·9
Chace No. 2600, annealed ..	48·7	42·0	1·1
Chace No. 2800, annealed ..	47·0	40·6	4·0

allows a very wide margin of safety and makes necessary the use of more bimetal than a less conservative value would. Stresses must be considered lowered due to "creep" which occurs at high temperatures.

For the calculation of forces exerted by bimetallic strips when subjected to deflections, the moduli of elasticity must be known. The brass-Invar type of bimetal has a modulus of elasticity of approximately 17,500,000 lb. per square inch and most of the medium- and high-temperature bimetals have moduli of elasticity close to 25,000,000 lb. per square inch. These values are for room temperatures; at elevated temperatures, the moduli of elasticity will be lowered from 10 per cent. to 20 per cent., depending upon the metal and the temperature rise. Hardness of bimetals varies considerably with analysis, degree of rolling, and heat treatment. In general, bimetals are relatively hard, the low-expansion side varying from 205 to 260 Brinell, while the high-expansion side of medium- and high-temperature metals varies from 230 to 300 Brinell. These hardnesses are of the same order as those of medium-hard cold-rolled spring materials. With the exception of brass-Invar and some special bimetals, most high-temperature, high-deflection-constant bimetals have very low thermal conductivity. This is due, firstly, to the fact that Invar is a very poor conductor of heat; secondly, heat-resisting chromium-nickel steels and similar alloys are also very poor conductors of heat. Since this is the case, most high-temperature bimetals are very poor conductors of heat. This should be borne in mind by designers of devices in which the bimetal is to be heated by conduction.

All manufacturers and most large users of bimetals have developed methods of test which meet their own particular requirements. While there may have been some similarity in the general test procedure, there usually existed enough difference to cause discrepancies in results when testing identical materials. To eliminate this difficulty, the American Society for Testing Materials formed Sub-Committee VII, under Committee B4, to study bimetals and set up methods of test. Their latest work may be found in Tentative Standard B106-39 T, entitled "Tentative Method of Test for Flexivity of Thermostatic Metals."

Application of Thermostatic Bimetals.—Space limitations do not allow enumeration of the very extensive uses of thermostatic bimetals. Suffice it to state that one manufacturer of bimetals lists in his catalogue 60 general industrial applications and 15 automotive, aviation, and marine applications. A number of articles have been written on the application of bimetals, showing the more common forms in which bimetal elements are used, *i.e.*, spirals, helixes, discs, flat and U-shaped strips and also special shapes to meet various unusual requirements.

Recently, two new bimetal units have been introduced, namely, a triple-helix and a double-helix coil. The triple helix was developed by the Western Electrical Instrument Corporation and is being used extensively in dial thermometers. By this method of winding a very sensitive element requiring small space is obtained. The double-helix coil is a product of the General Plate Company. This coil is made by winding a relatively long small-diameter helix into a much shorter helix of a considerably larger diameter. Upon heating, this helix produces a linear deflection along the main axis of the coil.

THE ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—We have been informed that all communications for the Association of Supervising Electrical Engineers, and in connection with *The Electrical Supervisor*, should now be addressed to Aldwych House, London, W.C.2, as the offices at Cockfosters, Barnet, Herts, have been closed.

ENGINEERING TRAINING AND EDUCATION.

Scholarships in Electrical Engineering.—Application forms, which must be returned not later than April 15, are invited for the Duddell, Ferranti, Swan Memorial, Silvanus Thompson, and William Beedie Esson scholarships, which are awarded by the Council of the Institution of Electrical Engineers. The Duddell scholarship is valued at 150*l.* per annum, and is tenable for three years; it is intended for candidates, under 19, wishing to take up a full-time day course in electrical engineering. The Ferranti post-graduate research scholarship is tenable for two years, is worth 250*l.* per annum, and is open to students under 26 years of age. The Swan Memorial Scholarship is also for post-graduate research. It is intended for students under 27, and is tenable for one year. Its value is 120*l.* The Silvanus Thompson Scholarship is intended for works employees, under 22 years of age, who are the sons of parents of limited means. It is valued at 100*l.* per annum, plus tuition fees, and is tenable for two years. The objects of the William Beedie Esson Scholarship are similar, and in both cases the successful candidate will be required to take up a full-time day course at an approved university or technical college. The value of the W. B. Esson Scholarship is 120*l.* per annum, and it is tenable for two years, but it is renewable in approved cases for a third year. All five scholarships are open to British subjects who must be under the age stated on July 1, 1940. Inquiries for further particulars and nomination forms, specifically mentioning the name of the scholarship, should be addressed to the Secretary of the Institution of Electrical Engineers, Savoy-place, London, W.C.2.

TENDERS.

WE have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Electric Lamps, gas-filled and vacuum, coil-filament type; and waterworks equipment, comprising chlorinating plant, complete with gauges, valves, and pressure pump and cast-iron water pipes, valves and a steel tank having a capacity of 20,000 gallons. Mosul Electricity and Water Board, Bagdad; March 16. (T. 15,998/40.)

Switchgear. Public Works Department, Wellington, N.Z.; March 12. (T.Y. 15,311/40.)

Buffers for the North Western Railway. Indian Stores Department, Engineering Branch, New Delhi; March 6. (T. 16,315/40.)

Ventilating Plants for the police mortuary, Johannesburg (T. 16,295/40), and for the Law Courts, Cape Town (T. 16,297/40). Union Tender and Supplies Board, Pretoria; March 14.

Steam Boiling Pans, steam calorifiers, hot-water storage cylinders, steam traps and steam boilers. Public Works Department, Johannesburg; March 7. (T. 16,298/40.)

Electric Passenger Lifts for Government Buildings, Barrack Square, Cape Town. Union Tender and Supplies Board, Pretoria; March 14. (T. 16,300/40.)

Vacuum-Brake Fittings for the Burma Railways, including ball and release valves, couplings, pipe hose, rubber washers and joint rings. Indian Stores Department, Miscellaneous Section, New Delhi; March 4. (T. 16,317/40.)

Vertical Steam Boiler for Fort Beaufort Mental Hospital Laundry, Cape Province. Union Tender and Supplies Board, Pretoria; March 14. (T. 16,299/40.)

Transformers, core-type, 22; sixteen three-phase (ranging from 5 kVA to 50 kVA), and six 3-kVA single-phase. Electricity Supply Commission, Cape Town; March 15. (T. 16,309/40.)

Cast-Iron Pipes, total length 355,400 m., in twelve batches ranging in diameter from 0·040 m. (1·57 in.) to 0·900 m. (35·4 in.). Argentine Sanitary Works Department, Buenos Aires; March 5. (T. 16,558/40.)

Motor Ambulance. General Stores Department, City of Durban, South Africa; March 15. (T. 16,332/40.)

INDUSTRIAL ACTIVITY IN THE UNITED STATES.—Statistics published by the Guaranty Trust Company of New York indicate that the production of steel ingots and of motor cars has declined in recent weeks. Further, the number of loaded goods wagons dealt with on the railways, and the output of electricity have also decreased latterly. These and other statistics, it is stated, indicate "an uninterrupted recession in general business activity."

PERSONAL.

Three appointments have recently been made in the Department of the Chief Engineer (Civil) of the London Passenger Transport Board, 55, Broadway, London, S.W.1. MR. H. J. GREEN has been promoted from the position of assistant chief engineer to that of deputy chief engineer, and MR. J. H. CONDY from that of civil engineer (maintenance) to that of assistant chief engineer. MR. J. W. CARSWELL has been appointed an officer of the Board, with the title of chief resident engineer.

MR. C. F. A. VOYSEY, F.R.I.B.A., has been awarded the Royal Gold Medal for Architecture.

The Controller of the Anglo-Spanish, Anglo-Roumanian, Anglo-Italian and Anglo-Turkish Clearing Offices announces that, as from February 26, the address of his offices is Ebury Bridge House, London, S.W.1.

MESSRS. A. C. WICKMAN, LIMITED, Coventry, inform us that they are now in a position to handle, exclusively, the contour measuring projectors, the optical protractors, the optical drill gauges, and the shop microscopes manufactured by Messrs. Bausch and Lomb Optical Company, Limited, London.

MR. H. BEER has been appointed private secretary and MR. R. B. TIPPETTS assistant private secretary, to SIR ANDREW DUNCAN, G.B.E., M.P., President of the Board of Trade.

MR. E. RAYMOND STREAT, C.B.E., Director and Secretary of the Manchester Chamber of Commerce, has been appointed Secretary to the Export Council, by the President of the Board of Trade.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Like the heavier branches of local industry, the lighter trades, devoted chiefly to the production of all types of tools and machine parts, are exceptionally busy. A large volume of business is being done in engineers' small tools, machine tools, hacksaws and blades, twist drills, reamers, milling cutters, and fine measuring tools. Sales are steadily expanding, and outputs are well in excess of those reached during the last war. File makers are busier. Activity is most intense in those departments producing all types of special steels. Makers of stainless steel report that production is well in excess of that of a year ago. For mechanical-engineering purposes the demand is considerable, while increased tonnages are being used in the manufacture of dairy equipment, refrigerating machinery, and pumping plant. Heat- and acid-resisting materials are finding a ready market, and tool steel is in strong demand. The call for agricultural machinery, parts and implements is well above the usual seasonal level. The heavy machinery and engineering branches report that the influx of orders shows no sign of falling off. Government requirements are considerable, and ordinary commercial business is on the increase.

South Yorkshire Coal Trade.—Larger supplies of coal are available for both industrial undertakings and householders. The market generally is brisk, and merchants are experiencing a busy time in clearing off the arrears of orders. Steam coal is in strong demand. The Bolsover Colliery Company reports the re-opening of the Deep Hard Seam at Bolsover, and at Creswell the deepening of one of the shafts has been completed; a seam of reasonable thickness and satisfactory analysis has been proved.

SHIPPING ACTIVITIES IN INDIA.—It is stated in *The Board of Trade Journal* that during the nine months ending December, 1939, the tonnage of vessels which entered ports in British India and cleared with cargoes, from and to British Possessions and foreign countries, totalled 7,051,000 and 6,874,000, respectively, as compared with 6,777,000 and 7,169,000 in the corresponding period of 1938.

A VETERAN RAILWAY WAGON.—A 40-ton special trolley railway wagon, built at the Derby works of the London Midland and Scottish Railway Company in 1884, is still in service. Specially designed for the conveyance of exceptional loads, such as armour plate, marine boilers, anchors, transformers and turbine castings, the wagon is sturdily constructed and has been effectively modernised from time to time. The veteran wagon, which is officially designated L.M.S. "BTZ" trolley No. 10,018, transported machinery and parts for our first large battleship, H.M.S. Dreadnought, and carried machinery and other munitions during the South African war of 1899-1902 and the European war of 1914-18. In recent years it has been carrying large electrical equipment for the Grid and it is now employed on conveying munitions for the third time in war. It is 37 ft. 6 in. long, runs on eight wheels and weighs 25½ tons without a load.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Very firm conditions ruled on the Welsh steam-coal market during the past week. Supplies of all descriptions were only sparingly offering to meet a brisk request from both home and foreign buyers. As a result, the amount of new business that operators could accept was again severely checked. Practically the whole of the output was earmarked for delivery under existing contracts, and order books were well filled over some months ahead. The occasional odd parcels coming on the market were quickly taken up at the recent high figures. South Wales miners, at a delegate conference held during the week, passed a motion asking the South Wales coalowners to give increased compensation, equal to the advances made in wages. The motion also called for generally increased rates of compensation, but condemned the suggestion, put forward by Government spokesmen, that the principle of a means or needs test be applied to workmen receiving compensation. Duff coals remained extremely scarce, and, as order books for these sorts are well filled over several months ahead, a strong tone ruled. Sized and large qualities were only sparingly offering for forward shipment and smalls were still limited. The demand for cokes and patent fuel was actively maintained.

The Iron and Steel Trade.—Active conditions ruled in the iron and steel and allied trades of South Wales and Monmouthshire last week. The works were again engaged almost to full capacity, and a brisk request was circulating for various products.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—No notable change has to be recorded this week in connection with the state of the Scottish steel trade. The shipyards are fully employed, and their requirements are accounting for a large tonnage of the output. Several welcome shipments of steel scrap have lately arrived, and the raw material position is again satisfactory. The black-steel sheet makers have heavy order books and in most cases the delivery date for new business is several months ahead. Overseas inquiries continue and a good tonnage is being shipped. The following are the current prices:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.*; sections, 12*l.* 8*s.* per ton; medium plates, under $\frac{3}{16}$ in. thick, weighing 6 lb. or more per square foot, 14*l.* per ton; weighing less than 6 lb. but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in 4-ton lots, 20*l.* per ton.

Malleable-Iron Trade.—A fair demand exists for bar-iron and steady employment is general. The re-rollers of steel bars are very busy. Fair consignments of semies have been coming in from overseas, but a larger tonnage is necessary. The current prices are as follows:—Crown bars, 12*l.* 17*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton; No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars, tested, in 4-ton lots, 14*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—There has been no falling-off in the demand for Scottish pig-iron and the current output is rapidly taken up. Steel makers are consuming large tonnages and are pressing for deliveries. Both hematite and basic iron are in great demand, but foundry grades are still dull and move slowly. The following are to-day's market prices:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

THE LATE MR. JOHN CRAIG.—It is with regret that we note the sudden death, on February 16, at his home in Monreith-road, Newlands, Glasgow, of Mr. John Craig, for many years a director of Messrs. G. and J. Weir, Limited, Cathcart, Glasgow, S.4. He was the son of the late Mr. George Craig, J.P., and was born at Newton Mearns, Renfrewshire, in June, 1874. He was educated at Glasgow High School and entered the works of Messrs. G. and J. Weir as an apprentice in August, 1890. After completing his apprenticeship, Mr. Craig served, in turn, in the drawing office and in the works office, before assisting Mr. (afterwards Sir) John Richmond in the estimating, sales and contracts departments of the business. He was elected to the board of directors in 1913, and, for a number of years prior to his retirement, last year, owing to failing health, he had controlled the estimating and contracts departments of his firm. In this position his long experience, sound judgment and extensive knowledge of the marine-engineering industry were of great value. He took little part in public life.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The distribution of iron and steel is now on a large scale and the maintenance of a high rate of production enables delivery licences to be issued more freely than for a considerable time to customers who have been seeking to place orders for their immediate needs. Producers report, however, that inquiries for early supply are such that forward business cannot be discussed.

Cleveland Iron Trade.—The supply of foundry iron is ample for current needs, though the output of Cleveland pig is still suspended. Regular deliveries of Midland brands cover the requirements of North of England founders. The merchants are handling very little local iron and much of the products from elsewhere are purchased directly by consumers from makers. The fixed prices of Cleveland pig remain on the basis of No. 3 description at 111*s.*, delivered within the Tees-side zone. Quotations for Continental foundry iron are still much too high to induce purchase.

Hematite.—Conditions in the East Coast hematite branch of the trade confine transactions to narrow limits, but deliveries are heavy. The tonnage accumulations of makers have been much reduced and are now almost as low as is desirable. Producers' own consuming departments continue to absorb most of the iron passing into use. Sellers are unwilling to enter into further extensive commitments until their delivery obligations have been considerably reduced. Second hands hold only small parcels of hematite. The stabilised quotations are ruled by No. 1 grade of iron at 127*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—Supplies of basic iron suffice for the requirements of makers' own steelworks, but there is none for sale and the quotation of 104*s.* 6*d.* is nominal.

Foreign Ore.—The position regarding foreign ore is satisfactory and promises to improve. Users have stocks that suffice for the present requirements and regular imports are expected to increase.

Blast-Furnace Coke.—Local consumers of Durham blast-furnace coke are receiving adequate deliveries and having made provision for their needs over a considerable period, are buying but little. Holders have good contracts to execute and are not desirous of selling at the recognised market values, which are governed by good medium qualities at 31*s.* 8*d.* at the ovens.

Manufactured Iron and Steel.—The make of semi-finished iron and steel and the imports of Continental semies are providing re-rollers with enough material to keep the mills very active. The finished industries are also turning out heavy tonnages in the various departments, with the exception of the branch engaged in the manufacture of light castings, which is slack owing to the decline in the building trade. Rollers of light bars, sections and sheets have many months work on hand, and pressure for the supply of shipbuilding requisites is increasing. Producers of heavy steel still have difficulty in supplying the heavy demands.

Scrap.—While the scarcity of iron and steel scrap is less acute than formerly, complaints of shortages of most descriptions are still heard. All available parcels are promptly purchased.

CHART FOR TREATMENT OF TOOL AND DIE STEELS.—Messrs. Thos. Firth and John Brown, Limited, Atlas and Norfolk Works, Sheffield, 1, have sent us a copy of a "Tool and Die-Steels Treatment Chart," recently prepared by them. The chart is intended for the guidance of foremen and charge hands and the heat-treatment to be given to high-speed, carbon and alloy die steels for various purposes is set out in detail. A colour-tempering chart for carbon-steel tools is also incorporated and the whole chart is varnished to give added protection in the workshop.

MAINTENANCE SCHOLARSHIPS IN ARCHITECTURE.—The Architects' Registration Council of the United Kingdom offers for award in June, 1940, certain maintenance scholarships in architecture. The scholarships will consist of a grant for the payment, in whole or in part, of the school fees, instruments, books, etc., and, when necessary, a maintenance allowance not to exceed, as a rule, 100*l.* a year. The scholarships will be renewable from year to year until the student has finished his or her training. They will be available for students of British nationality, who could not otherwise afford such training, to enable them to attend architectural schools approved by the Council. They would not normally be granted to students under 17 years of age. Particulars and forms of application may be obtained from the Secretary to the Board of Architectural Education, Architects' Registration Council of the United Kingdom, 68, Portland-place, London, W.1. The closing date for the receipt of applications, duly completed, is March 26.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF MECHANICAL ENGINEERS.—*Steam Group:* To-night, 6 p.m., Storey's Gate, Westminster, S.W.1. Extra General Meeting. "Circulation of Water and Steam in Water-Tube Boilers, and the Rational Simplification of Boiler Design," by Messrs. W. Y. Lewis and S. A. Robertson.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Meter and Instrument Section:* To-night, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. "A Method of Measuring and Recording the Frequency Error of A.-C. Power Supplies," by Mr. F. O. Morrell. Followed by demonstration of quartz-crystal clock, by Mr. L. Essen. *Mersey and North Wales (Liverpool) Centre:* Monday, March 4, 6.15 p.m., The Liverpool Royal Institution, Colquitt-street, Liverpool. "Oil-less Metal-Clad Switchgear for Medium-Voltage A.-C. Circuits up to 660 Volts, Three-Phase," by Messrs. H. E. Cox and L. Drucquer. *Wireless Section:* Wednesday, March 6, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. "Wire Broadcasting Investigations at Audio and Carrier Frequencies," by Dr. T. Walmsley. *Tees-side Sub-Centre:* Wednesday, March 6, 6.45 p.m., Cleveland Scientific and Technical Institute, Corporation-road, Middlesbrough. "Electronic Musical Instruments and the Development of the Pipeless Organ," by Messrs. G. T. Winch and A. M. Midgley. *Institution:* Thursday, March 7, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Ordinary Meeting. "Oil-less Metal-Clad Switchgear for Medium-Voltage A.-C. Circuits up to 660 Volts, Three-Phase," by Messrs. H. E. Cox and L. Drucquer. *North Midland Centre:* Saturday, March 9, 2 p.m., Hotel Metropole, King-street, Leeds. Discussion on "Fire-Fighting Equipment for Electrical Installations," to be introduced by Messrs. J. Hacking and R. A. McMahon.

JUNIOR INSTITUTION OF ENGINEERS.—*Sheffield Section:* To-night, 7.30 p.m., Sheffield Metallurgical Club, West-street, Sheffield. Presidential Address: "Mechanical Properties in Relation to Design," by Professor H. W. Swift.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Lancashire Branch:* Saturday, March 2, 3 p.m., Engineers' Club, Albert-square, Manchester. "The Production of Some Engineering Castings," by Mr. A. Marshall. *Scottish Branch:* Saturday, March 9, 3.30 p.m., Royal Technical College, George-street, Glasgow. Annual General Meeting, and "Notes on the Production of Some Engineering Castings," by Mr. A. Marshall.

BRADFORD ENGINEERING SOCIETY.—Monday, March 4, 7.30 p.m., The Technical College, Great Horton-road, Bradford. "The Operation, Development, and Maintenance of Automobile Electrical Equipment," by Mr. W. Marshall.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 5, 5.30 p.m., Great George-street, Westminster, S.W.1. Vernon-Harcourt Lecture. "The Construction of Deep-Water Quays," by Mr. A. C. Gardner.

INSTITUTION OF AUTOMOBILE ENGINEERS.—Tuesday, March 5, 6 p.m., The Royal Society of Arts, John Adam-street, Adelphi, W.C.2. "Some Problems We Meet," by Mr. L. H. Dawtrey.

INSTITUTION OF ENGINEERS-IN-CHARGE.—Tuesday, March 5, 6.30 p.m., Messrs. The General Electric Company, Limited, Magnet House, Kingsway, W.C.2. Joint Meeting with ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS. "The Principles and Practice of Discharge Lighting," by Mr. R. O. Ackerley.

SHEFFIELD METALLURGICAL ASSOCIATION.—Tuesday, March 5, 6.30 p.m., 198, West-street, Sheffield, 1. "Modern De-Oxidation Practice for Steel," by Mr. Howard Biers.

INSTITUTION OF PRODUCTION ENGINEERS.—*Luton Section:* Tuesday, March 5, 7.30 p.m., The George Hotel, Luton. "Nitralloy Steels and Their Application," by Dr. W. H. Hatfield.

INSTITUTE OF METALS.—Wednesday, March 6, 2.30 p.m., 4, Grosvenor-gardens, S.W.1. Annual General Meeting. For programme, see page 112, *ante*.

ROYAL INSTITUTION.—Wednesday, March 6, 5.15 p.m., 21, Albemarle-street, W.1. "X-Ray Optics," by Professor W. L. Bragg. Friday, March 8, 5 p.m., "Experiments from the Researches of Sir James Dewar," by Sir William Bragg.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, March 8, 6 p.m., Mining Institute, Newcastle-upon-Tyne. "Mean Pitch Determination of Variable-Pitch Propeller," by Dr. E. V. Telfer.

ROLLING STOCK FOR THE LIVERPOOL AND SOUTHPORT LINE, L.M.S.R.

MR. W. A. STANIER, M.I.MECH.E., CHIEF MECHANICAL ENGINEER.

(*For Description, see Page 222.*)

FIG. 5. GENERAL VIEW OF THREE-CAR TRAIN.

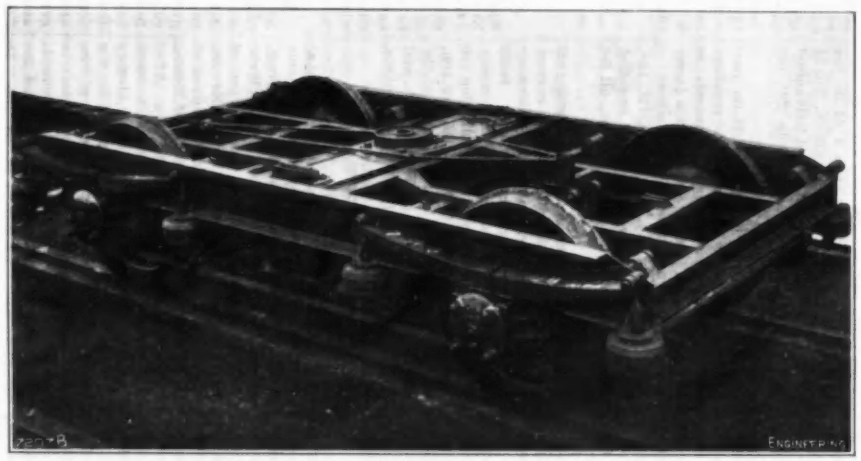


FIG. 6. TRAILER-CAR BOGIE.

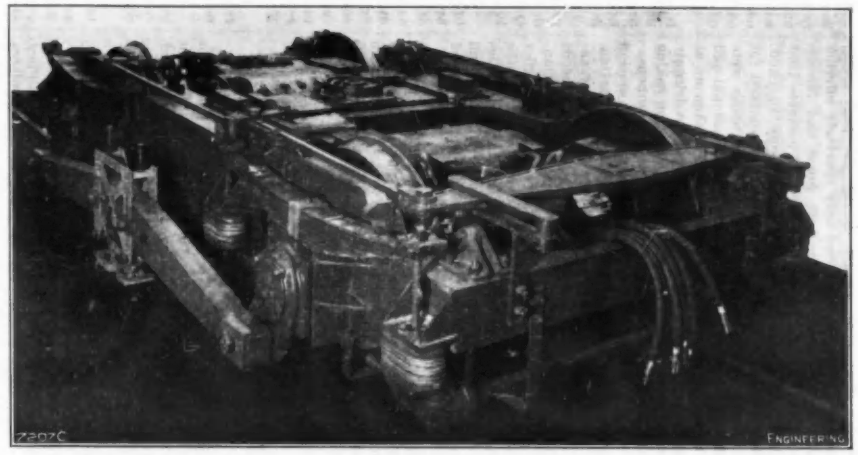


FIG. 7. MOTOR-CAR BOGIE.

THE DEVELOPMENT OF IRRIGATION THROUGH THE AGES.

(*For Description, see Page* 235.)

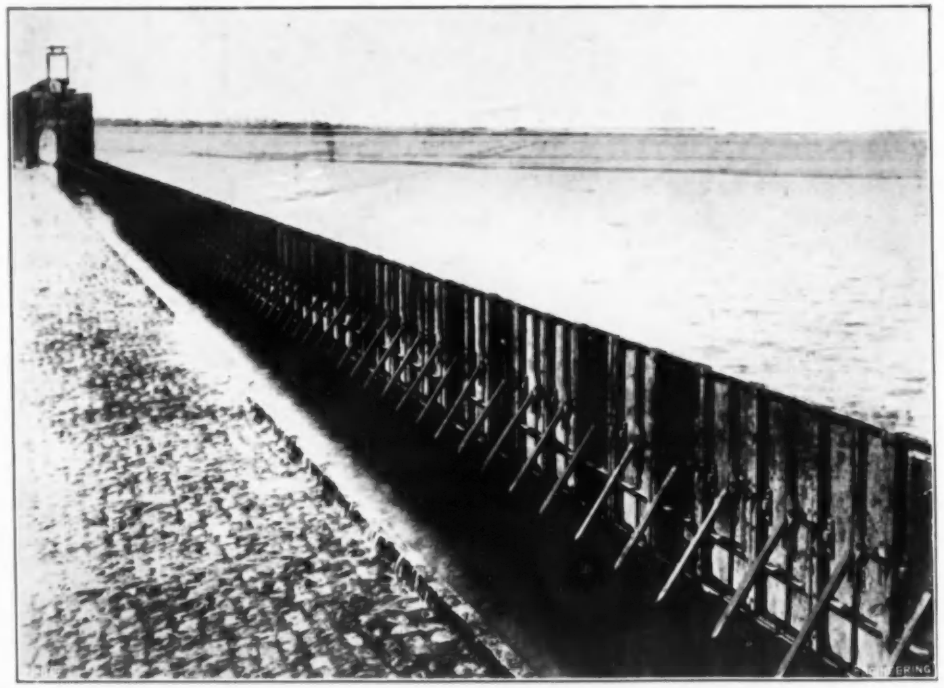


Fig. 5. Dam Formed of Automatically-Collapsing Shutters.

Fig. 6. Collapsing Shutters being Re-Set by Manual Labour.

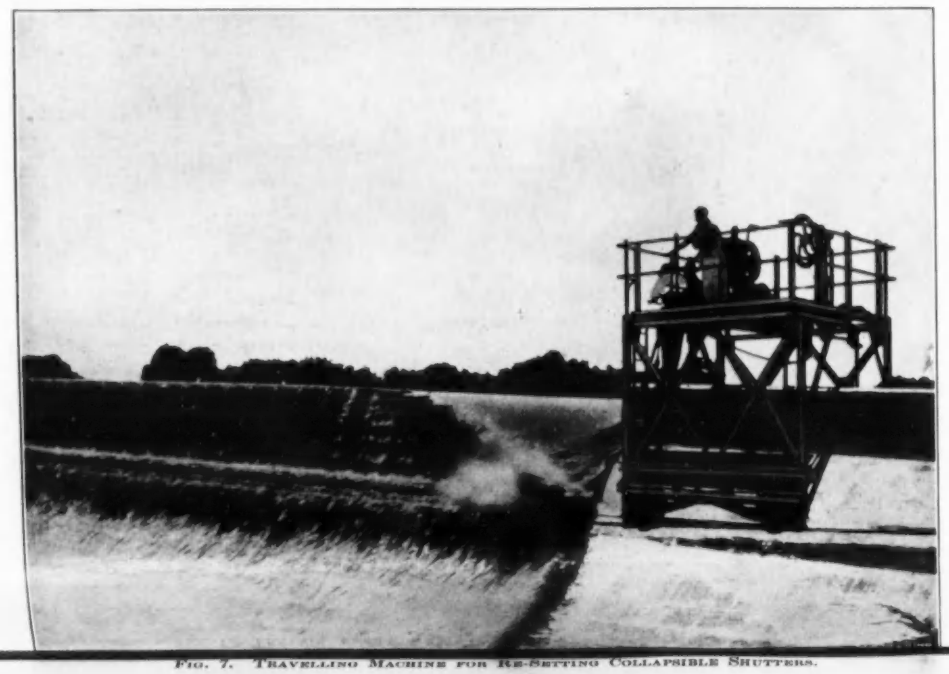


Fig. 7. Travelling Machine for Re-Setting Collapsible Shutters.

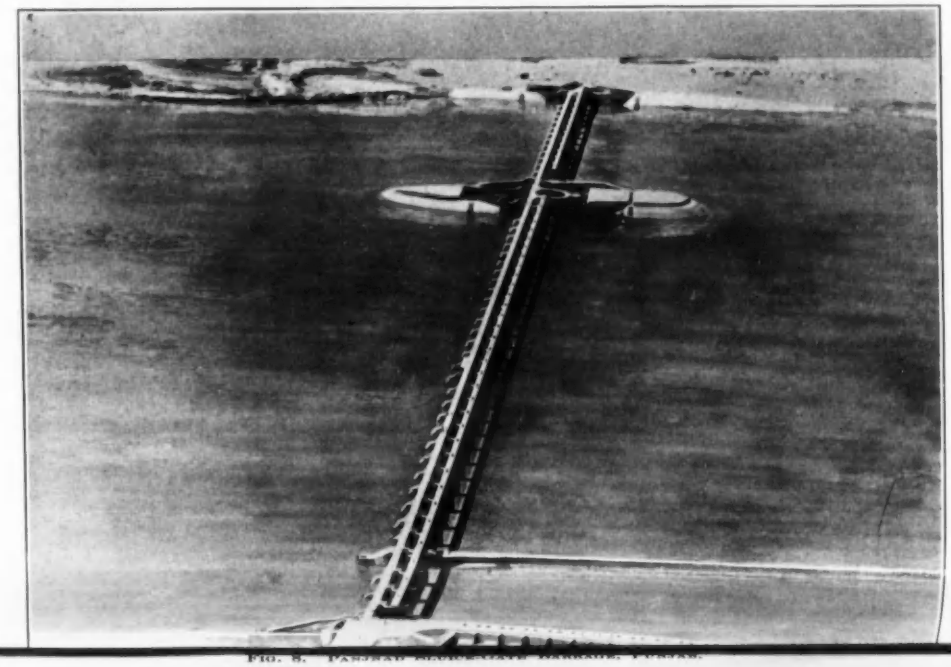


Fig. 8. Pressed Concrete Barrier, Persia.

Fig. 7. Travelling Machine for Re-Setting Collapsible Shutters.

Fig. 8. [illegible]

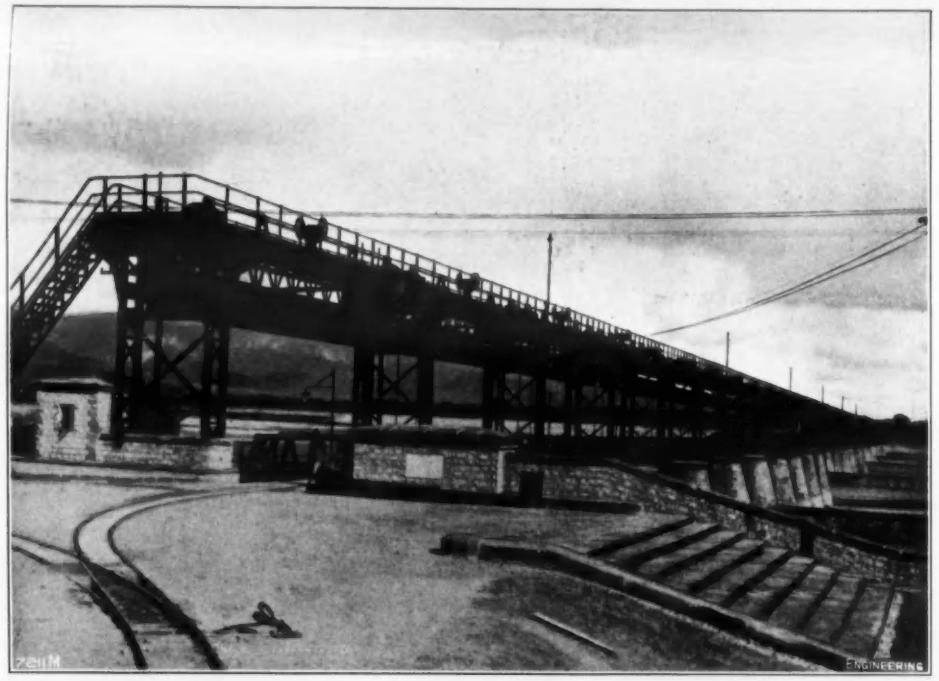


Fig. 9. Barrage on the Sarda River, United Province.

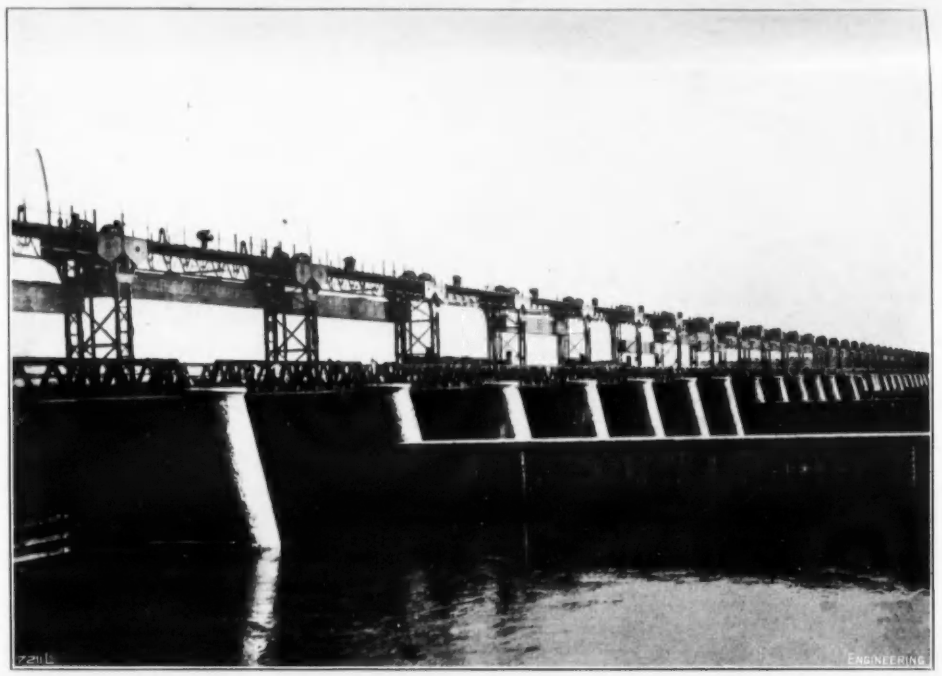


Fig. 10. Overhead Independent Lifting Gear; Sarda Barrage.

Fig. 11. Independent Motor-Operated Sluice Gate.

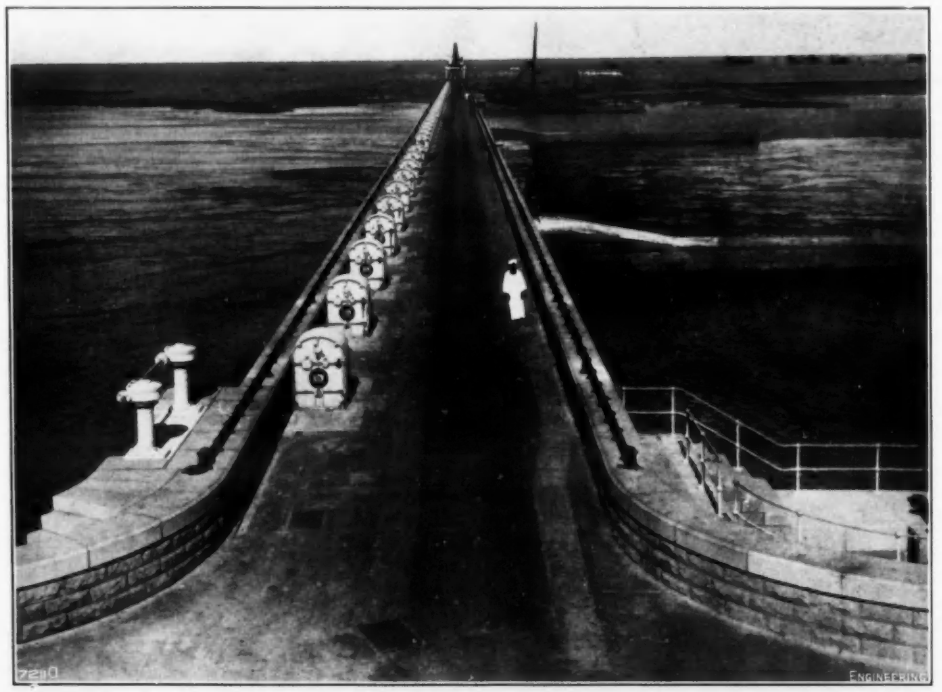


Fig. 12. Gebel Aulia Dam on the White Nile.

UNIV. OF MICH.

ENGINEERING.

Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," LESQUARE LONDON.

TELEPHONE NUMBER—TEMPLE BAR 3663 (2 lines).

SUBSCRIPTIONS, HOME AND FOREIGN.

"ENGINEERING" may be ordered from any newsagent in town and country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance :—

For the United Kingdom	£3 5 0
For Canada—	
Thin paper copies	£2 18 6
Thick paper copies	£3 3 0
For all other places abroad—	
Thin paper copies	£3 3 0
Thick paper copies	£3 7 6

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines, or under, and one shilling per line up to one inch. The line averages six words. When an advertisement measures an inch or more the charge is 12*s.* per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns, of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but cannot be guaranteed.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

CONTENTS.

	PAGE
New Method of Constructing French Curves (*Illus.*)	215
Efficiency in Documentation	217
The Engineering Outlook—VI	218
Electrolimit Gauges (*Illus.*)	220
New Rolling Stock for the Liverpool and Southport Line, L.M.S.R. (*Illus.*)	222
Thermostatic Bimetals	223
Engineering Training and Education	224
Tenders	224
Personal	224
Notes from South Yorkshire	224
Notes from the South-West	225
Notes from the North	225
Notes from Cleveland and the Northern Counties	225
Notices of Meetings	225
Training Labour for Munitions	227
Some Practical Aspects of Earthing	228
Notes	229
The Pumping of Granular Solids in Fluid Suspension	230
Metals as Engineering Materials—II	231
The Late Professor F. P. Purvis	232
Experiences with High-Temperature High-Pressure Stations	232
Ultra-Rapid Voltage Regulator (*Illus.*)	232
The Unw'n Memorial Fund	233
Labour Notes	234
Irrigation Through the Ages (*Illus.*)	235
Welding as a Substitute for Casting	237
Triple-Helical Speed-Reducing Gear (*Illus.*)	239
Electricity Supply in Ireland	239
Catalogues	239
"ENGINEERING" Patent Record (*Illus.*)	240

One Two-Page Plate.—THE DEVELOPMENT OF IRRIGATION THROUGH THE AGES.

ENGINEERING

FRIDAY, MARCH 1, 1940.

VOL. 149. No. 3868.

TRAINING LABOUR FOR MUNITIONS.

THE day after the war broke out, large engineering shops in France found themselves with half, or less than half, the hands they had the day before. The missing men had been called to the colours. This procedure was dictated by the necessity of meeting a possible sudden onslaught on the French frontier—a consideration which had to take precedence of all others. Clearly, however, it must have seriously upset engineering production, which, unfortunately, in the nineteen hundred and fortieth year of the Christian era, means armament production. The initial disarrangement has long been rectified, partly by bringing skilled men back from the front, but largely by drafting new labour to the factories. This has included a large proportion of women.

No comparable situation arose in this country. The proportion of our workpeople who were army reservists or Territorials was relatively so much smaller that their withdrawal did not raise the same problems ; while the rate at which the various age groups are now being called up, together with the early notification of the time at which the groups are to report, allows industry to adjust itself with greater leisure. Further, the operation of the schedule of reserved occupations should prevent the embarrassment of the engineering industry by the withdrawal of really skilled hands. This, however, does not mean that that industry is going to be left alone to carry on as if nothing had happened. Some two million more men will be called up this year and it is certain that engineers will neither expect nor desire that the service which these men will render should be entirely performed by industries other than their own. Even should they, the technical requirements of a modern army require that more than a sprinkling of its personnel shall have technical qualifications and the necessary men must be furnished by the technical industries.

In spite of well-meant efforts, skilled engineers cannot be produced by a few months training, either in peace time or under the impetus of a war, and the technical staffs of the engineering industry must be prepared to carry a load of responsibility enormously increased by the conditions in which we now find ourselves. They did this twenty-five years ago and can do it again. The training of miscellaneous labour to such a degree that it can take a useful place in engineering factories, however, is another matter. This also was done twenty-five years ago and can be done again. All that need be asked is that an effort should be made to do it better this time. During the last war, although a considerable amount of training was carried out, tens of thousands of labourers and women, or men of other trades, were, none the less, taken on in our munition factories and employed on semi-skilled operations. In very many cases the only training they had was on the job on which they were employed. The early stages of this procedure was, perhaps, productive of rather a large proportion of scrap, but those who had experience of, say, the machining of shell bodies, by workpeople who a few weeks before had never seen a machine tool, will testify to the high degree of skill which was attained in a limited sphere.

As, during the last war, we were rather slow in getting into our stride, the adoption of emergency arrangements was essential and new factories had to start up with the labour which was available. This time, we had a better idea of what was coming and many preparations had been made before the beginning of last September. Nevertheless, all that we were to do was by no means in operational order at that time. It is common knowledge that our output of munitions and armaments of every type is increasing every day and we have been officially told that many large new factories will shortly come into operation, with a resultant demand for labour such that "the job will be looking for the man." To a very large extent that man is now unskilled and if, before these new factories come into production, he can be given some preliminary training, it will facilitate the work of many overloaded works managers and tend to reduce the amount of spoiled work.

Our figures for unemployment have long been a matter for dissatisfaction in this country and for jibes in Germany. They have, however, the quality of honesty, and usually include a considerable number of workpeople who are in process of changing their jobs, or are temporarily unemployed owing to weather or other uncontrollable conditions. They also carry a considerable weight of unemployables. Allowing for these deductions, the figures show that even in these times there are large numbers of people out of work. Pending the time when that job will be looking for them, it would appear wise that the opportunity should be taken to give them some preliminary training. A very definite effort in this direction is now being made by the Government Training Centres, which are operated by the Ministry of Labour. These Centres, the first of which was established in 1925, have been doing useful work which has received but small public recognition. Organised labour has taken little interest in them, possibly because they have operated on a comparatively small scale.

There are now 14 main centres and eight local centres, these latter having been established in areas where there has been grave unemployment. The centres have up to the present been able to deal with 8,000 men at a time. This figure is now to be raised to 15,000, and it is hoped to train 40,000 men, to a stage which will make them useful in industry, by the end of the year. Admission to the centres is restricted to men between the ages of 25 and 45, who may take any of the courses offered. Men of 18 and 19 are admitted for the engineering courses only, although those between the ages of 20 and 25 who are medically unfit for military service may also be taken. The training courses cover a period of six months, the subjects dealt with being machine operation, fitting and turning, electrical and oxy-acetylene welding, sheet-metal work, and instrument making. The subject of draughtsmanship is also included, the course in this case covering nine months. Unemployed men entering the centres continue to draw their unemployment pay and receive a training allowance in addition. The centres are well distributed about the

country, there being one each in Glasgow, Birmingham, Bristol, and on the North-East Coast; four in the neighbourhood of London; one in Southampton; one in Leeds, etc.

Although, at first sight, the practising engineer will feel doubtful about the value of a draughtsman produced from a non-engineering individual by even nine months training, it must be remembered that the Training Centres are open to all unemployed, including black-coated workers, and it is possible that among these, in the sphere of architecture, for instance, which has been seriously disorganised by the war, men may be found who may make quite useful draughtsmen in a specific and limited sphere. Not all professional draughtsmen can turn their hand to any branch of the engineering field. In any case, trainee draughtsmen can form but a very small part of the total, and it is the machine operators, fitters and welders who will be in demand. It is clear that in these fields widely varying degrees of skill are required; it may be assumed that, when the Training Centres talk of producing a machine operator, they mean something more than a man who can load and operate the controls of a single-purpose machine. They must intend a man who can do his own setting up. If they can produce such men in any considerable quantity, it will be a valuable contribution to our war effort. Similarly, in the case of welding, it should be possible to turn out men capable of working to a large extent without outside assistance. The production of men who, if only on a limited range of work, can take their place beside the skilled men of an industry will raise many questions of union labour, which it is not the purpose of this article to discuss. These matters may be left for another occasion; plenty will be heard about them before the bells ring in Warsaw.

It is clear that the 40,000 men which the Training Centres aim at producing per year, although a useful contribution, will be far from enough to meet the requirements of the war machine when it is in full operation. The experience of 1914-18 would be sufficient to prove this, even if we had no information about the factory extensions and enlargements now in process of being carried out. If any surprise is felt that we have not yet reached the condition of 1918, or that it should be possible to have any unemployed at all in war time, it is sufficient to remember that we have been at war, as yet, for less than six months and that engineering factories dealing with complicated products cannot be set up and brought into operation in a few weeks. The fact that labour is still available is not an indication that we have not reached the productive capacity of the closing years of the last war. We have already far exceeded it, but, thanks to the improved production methods which have developed in the last quarter of a century, with less improvisation and less labour wastage than before. When our full effort has been put out, we shall see a repetition of what we have seen before and every available labour unit with some job to hand.

In these circumstances, it would appear that industry itself might consider the desirability of introducing schemes for training its own semi-skilled labour, in order to supplement the supply which the Training Centres are providing. Although, as already mentioned, unskilled labour was engaged during the last war and put straight on to production, it would have been an advantage if that labour could have had some preliminary instruction. One of the reasons for the success achieved was that very much work was done at that time on simple machines, the production of a shell body, for instance, being divided into perhaps a dozen different operations, carried out on different machines. The reason for the present much larger output of shells, with a smaller labour force, is that the earlier system, which was expensive both in labour, space and transport, has been replaced by more modern methods. One result of this, however, is that the machine tools are more complicated and are not suitable for committing to the mercy of an unskilled labourer or girl. In spite of improved methods, a condition will arise resembling that in this country in 1918, and in France to-day, in which workpeople of all kinds will be found crowding our munition factories, and it would appear to be in the interest of some of our large firms, on whom a large part of the load will fall, without delay to initiate training schemes, so that the unskilled labour which they will be compelled to engage shall have at least some elementary conception of shop methods. Although we are not discussing the question of women labour at the moment, it is pertinent to point out that the various training factories, set up in the last war, dealt with women as well as men.

SOME PRACTICAL ASPECTS OF EARTHING.

Electrical apparatus contains a great deal of metal work, some of which is used for carrying current, while the rest is required for structural purposes or for protection. The regulations issued by the Electricity Commissioners lay down that the non-current-carrying metal parts shall be "connected with the general mass of earth in such a manner as will ensure at all times an immediate and safe discharge of energy," and also state the conditions under which this earthing is to be effected. For instance, there must be only one neutral-point earth on each high-voltage system, while on low-voltage networks each system fed by a substation must be earthed at one point and the neutral must be insulated throughout its length. With the increase in the size of transmission and distribution networks, these apparently simple conditions are not always easy to fulfil, the reason being that the resistance of the "earth" may be high compared with that of the system itself; and that in certain circumstances, therefore, the protection afforded may become fallacious. This is particularly the case in rural areas, where the resistivity of the soil may be high and where, as a result of lack of care in the selection of the "earth," voltage gradients may be set up which, experience shows, are dangerous to cattle if not to human life.

Efficient earthing, moreover, is necessary to ensure the proper operation of the protective apparatus, the dual objects of which are to prevent damage to expensive plant and, while isolating the faulty section, to cause a minimum of disturbance in the continuity of the supply. There is still much ignorance about the conditions which an earth should fulfil, as is shown by an example given in a recent report on electrical accidents, where it was thought sufficient to put the earth wire in a bucket of water which was itself usually placed on a piece of wood "to avoid leakage." It is also perhaps illustrated in another way by the proposal of the Central Electricity Board to instal eight ½-in. copper rods, 32 ft. long, to secure a resistance of less than 1 ohm, in a soil having a resistivity of 15,000 ohms per square centimetre.

It is clear that, if only for economic reasons, something ought to be done to reduce such a range of practice, and as Messrs. E. Fawssett, H. W. Grimmitt, G. F. Shotter, and H. G. Taylor point out in a paper on "Practical Aspects of Earthing," which was read on Wednesday, February 14, before the Transmission Section of the Institution of Electrical Engineers, the first thing to do is to discover a method of measurement and to use it to make systematic tests. The problem has recently been attacked on these lines by the British Electrical and Allied Industries Research Association. The paper gives a comprehensive account of the work to date, and, considering the importance of the subject, is deserving of close study.

The natural starting point of such a survey is a study of the electrodes by which the necessary connection is made to earth. These either comprise plates, strips, pipes, rods, or specially-designed equipment, which are employed for that purpose and no other, or water pipes, frameworks of buildings and cable sheaths and armouring, which have other uses as well. At power and substations, the commonest type of electrode is the cast-iron plate or pipe; though, recently, ¾ in. or 1 in. rods, 6 ft. long, have been increasingly used, especially for earthing overhead lines at rural substations and on consumers' premises. Buried strips and conductors are also being employed, particularly for rural substation earthing, where there is a layer of low-resistivity soil over a high-resistivity chalk or igneous rock. A third form of electrode, which has been used experimentally, is the coke trench. Experiments on these various types of electrode, described in the paper, show that the best results are obtained with small-diameter copper rods and that these should be driven as far as possible into the soil. For instance, one particular series of tests indicated that, while the resistance of an electrode was 110 ohms when it was driven to a depth of 3 ft., this decreased to as little as 2 ohms when the depth was increased to 36 ft. In another test, the resistance fell from 275 ohms at a depth of 1 ft. to 3·8 ohms at a depth of 15 ft. 6 in., while, in a third, the average resistivity at a depth of 12 ft. was less than a quarter of the value at 3 ft.

The next point which had to be examined was the resistivity of the soil itself, since the resistance of any earth electrode depends directly upon this factor. The resistivity of the moisture in the soil is determined by the nature and concentration of the soluble salts, by the temperature (since electrolytes have a temperature coefficient of about 2 per cent. per degree C.), and by the bacteriological activity. In mountainous districts the soils may be very wet and yet have a resistivity of 20,000 ohms per square centimetre owing to the purity of the water. Soils of a calcareous or rocky nature also have a high resistivity and in districts where they occur the superficial layer of soil should be used for earthing by driving the electrodes horizontally. This, however, exposes the electrodes to the risk of freezing, which also greatly increases the soil resistivity. A series of experiments was made to discover whether a reduction of resistance could be effected by salting, and the frequency with which it was necessary that re-salting should be carried out. Though these tests are not yet complete, the results seem to indicate that changes due to salting take place slowly and that in some instances it is years before the resistance reaches its minimum value. The return to normal also occurs at a variable rate, being high in pervious soils and low in impervious ones. Salting also increases the rate of corrosion, but if either plain or tinned copper is used the results are not serious.

Another point upon which tests were made is whether seasonal variations in the resistance of electrodes occur. The results appear to show that, except in the case of chalk, the variations are not large, though in some soils electrodes may take several years to recover from an unusually dry season. In fact, over test periods of four to seven years, the maximum resistance variation due to soil moisture was found to be 6 to 1, one value of 4·3 to 1 occurred, and the remaining 56 values were all less than 3·5 to 1. There was no great difference between chalks and clays, but the deeper the electrode was driven the less the seasonal variation. This increases the advantages of this form of installation, to which attention has already been directed. In peaty soil the changes are very small and there is no great difference between salted and unsalted electrodes. The benefits of deep burial are also emphasised by the occurrence of voltage gradients round earth electrodes. When current flows to earth from an electrode a voltage gradient exists on the surface of the ground. At large substations this may cause the insulation of telephone and pilot cables to break down under fault conditions, and, as we have already said, may expose cattle to risks of shock. This is especially likely to occur at the base of pole-mounted transformer substations, where the earth-fault resistance is such that the faults are not cleared at once. The remedy is to bury the electrode deeply and to make connection to it by an insulated lead.

An earth electrode should, however, be designed not only to have the resistance required and a non-dangerous voltage gradient, but a loading capacity adequate for the system of which it forms a part. Despite the importance of this last feature, very little work has been done on the subject and its neglect has sometimes given rise to trouble. The introduction of Petersen coils is likely to bring the matter more to the front in future, since with such devices heavy earth currents can be carried for some hours. In any event, the general increase in the capacity of systems warrants the determination of this factor more precisely. In this connection, three conditions have to be consi-

dered: long-duration loading in which the temperature of the whole neighbouring soil is raised; short-time overloads, which give rise to drying of the soil adjacent to the electrodes; and long-time overloads, in which the rate of heating is in excess of that for long-duration loading. The results obtained under any of these conditions also depend on whether alternating or direct current is being used. The work on this subject is also incomplete, so far, but the authors give the results of some tests that have been made in clay. In such soil, failure of the electrode occurs when a temperature of about 100 deg. C. is reached at its surface, as the moisture then evaporates and the resistivity increases to a very high value. The time taken to reach failure depends on the type of loading and can be determined from a knowledge of the characteristics of the electrodes and the soil. Small alternating-current leakage currents do not impair the characteristic of the electrodes. On the other hand, direct current can create difficulties if the electrode is connected to a positive lead. The overload capacity of a salted electrode is higher than an unsalted one and a coke-treated electrode is preferable to one that is untreated, if the amount of coke is sufficient to increase considerably the surface contact. Heating the soil round the electrode has the advantage that the moisture absorbs an increased amount of salts, which may remain in solution and decrease the resistivity when the temperature falls. The overload capacity of an electrode is about the same with both alternating and direct-current and, unless the temperature of the electrode is about 100 deg., the voltage gradient at the ground surface does not alter sufficiently to give rise to risk of shock.

As a result of the experimental data thus painstakingly collected, the authors conclude that an earth electrode installation must have a sufficiently low resistance to pass enough current to operate the protective gear on a fault, and must have adequate carrying capacity to maintain the fault current long enough for this gear to operate. The voltage gradient on the surface must not be dangerously steep and the electrode and its connection must have a high resistance to corrosion. In some cases it must have a low range of impedance to prevent a flash-over from earthed metal to insulated conductors when a lightning discharge takes place.

It will be seen, therefore, that there is good justification for the claim that, while complete information is not yet available on all aspects of earthing, sufficient data has been accumulated to convert it from a rule of thumb method to a scientific process based on a precise knowledge of correct flow from non-geometrically shaped conductors in a semi-conducting medium of varying resistivity. In fact, the degree of precision with which electrodes can be produced is only limited by uncertainty as to the resistivity of the soil in which they are buried, and this is best determined in individual cases by a preliminary test on site with a rod electrode.

NOTES.

Electrical Development in War Time.

At the beginning of the war, the Treasury issued a circular dealing with the raising of money for capital purposes by electricity supply undertakings and intimating that consent to such borrowing would only be given if the project were of pressing necessity, either for reasons of public need or on account of war requirements. This statement of policy has been regarded by some undertakings as placing an embargo on the supply of electricity to any new consumers, except where this is required directly for war purposes. Development has been retarded, therefore, while in some cases unemployment has been caused. To clarify the position, the Electricity Commissioners have now sent a letter to undertakings pointing out that it was not the intention of the circular to prohibit undertakings from complying with any statutory obligations or from meeting reasonable domestic and commercial demands, so long as the necessary mains, service materials and consumers' apparatus were readily available. On the other hand, there can be no question of undertakings endeavouring under war conditions to proceed with the development of their undertakings to the same extent as in normal times or to provide as complete facilities as formerly to consumers in the way of assisted wiring and hire or hire-purchase of apparatus. It is further pointed out that undertakings must distinguish between necessary work and that which could be postponed without undue hardship. Care must also be taken not to deplete stocks which are being held to repair eventual damage caused by air raids. Any additions to or modifications of distribution systems should be confined to those necessary to meet demands, firstly, for supplies for war purposes, or, secondly, for pressing domestic and commercial needs and to maintain supply voltages within the prescribed limits. Any work on change-over from direct to alternating current should be limited to the minimum necessary for avoiding expenditure on converting plant and direct-current mains. Finally, expenditure should be met as far as possible out of revenue.

Censorship and Science.

At the request of Sir Walter Monckton, Director-General of the Press and Censorship Bureau, Sir William Bragg, as President of the Royal Society, has undertaken the formation of a scientific panel to assist the bureau in arranging the censorship of papers in scientific journals. The panel consists of Professor C. R. Harington (biochemistry), Professor V. H. Blackman (botany and agriculture), Professor A. C. Egerton (chemistry), Dr. H. L. Guy (engineering sciences), Professor P. L. H. Boswell (geology), Professor S. Chapman (mathematics), Dr. C. H. Desch (metallurgy), Dr. C. G. Darwin (physics), Professor A. V. Hill (physiology), Professor F. C. Bartlett (psychology), Professor W. W. C. Topley (bacteriology and pathology), Professor M. Greenwood (statistics), and Sir Guy Marshall (zoology). The difficulty of ensuring an efficient and fair censorship of technical matter is considerable, as we have reason to know, but it is immeasurably enhanced when the subject belongs to the higher categories of scientific specialisation. To put such material through the mill of routine Press censorship would be neither efficient nor fair, yet to allow it to pass uncensored might convey, in perhaps one case in a hundred, some valuable clue to an alert enemy, fully alive to the uses of scientific research in warfare. The scope of the studies represented by the members of the panel is sufficient indication of the scale of modern war, which not only presses into its service men and women of all ages, but also includes among its possible lines of attack or defence the whole gamut of what used to be regarded as the liberal arts and sciences.

Shipbuilding and Engineering in Japan.

The recent death of Professor F. P. Purvis, an obituary notice of whom appears on page 232, and his long association with technical education in Japan, recalls the little-known history of the rise of shipbuilding and engineering in that country. It is now nearly eighty years since five young Japanese came to England in one of the sailing ships of Jardine, Matheson and Company, to study Western civilisation, and found a friend in Dr. A. W. Williamson (1824-1904), then professor of chemistry at University College, London, and president of the Chemical Society. All five rose to distinguished positions, and one of them, Viscount Yozo Yamao, constructed and operated the first railways in Japan. In 1872, it was decided to found an engineering school in Tokyo, which ultimately formed the nucleus of the Tokyo Imperial University. Of this school or college, Dr. Henry Dyer (1848-1918), a graduate of Glasgow University, who had learned his engineering under Dr. A. C. Kirk, became the principal. In 1873, he was joined by the mathematician and physicist, D. H. Marshall, later professor of physics at Queen's University, Kingston, Canada; Professor Thomas Alexander, who taught civil engineering; and by Edward Divers (1837-1912), who, after occupying the chair of chemistry for nine years, in 1882 succeeded Dyer as Principal, a post he held until 1899. In the 'seventies, Dyer's staff also included, for varying periods, John Perry, W. E. Ayrton, J. A. Ewing, and John Milne, the seismologist, who, while teaching geology and mining, studied earthquakes, and, in 1880, with some of his colleagues, founded the Seismological Society of Japan. Of the country as seen by these engineers, Ewing, who was there from 1878 to 1883, wrote: "The Japan of those days was venerable in its traditions, its literature, its art, its manners, its high standards of patriotism and of personal duty. It was almost painfully young in the veneer of Western culture which it had begun eagerly to acquire. To an inexperienced teacher there was stimulus and help in pupils whose polite acceptance of everything he put before them was no less remarkable than their quick intelligence and receptiveness. They were tolerant, they were apt, most of them were personally attractive." No one of those who were associated with the progress of technical education in Japan was held in higher regard than Charles Dickenson West (1847-1908), who, on Dyer's return home in 1882, became professor of mechanical and marine engineering, a position which he held until his death in Tokyo on January 10, 1908. The esteem that was felt for both Divers and West was shown by the erection of monuments to them in the university grounds. It was, in 1883, apparently, under West, that the late Professor S. Miyoshi, fresh from the shipbuilding yard of Robert Napier and Sons, began teaching naval architecture in Tokyo. The growing interest in all appertaining to shipping, however, led the authorities in 1898 again to seek assistance from Great Britain, and in that year Dr. P. A. Hillhouse, then at the Clydebank shipyard, was appointed to the chair of naval architecture. On his resignation in 1902, Professor Purvis succeeded him. At that time, both the Japanese Navy and the Mercantile Marine were making great strides, and before Professor Purvis returned to England, Japan had become one of the chief shipbuilding nations. In 1900, Japanese yards launched three vessels, with a total tonnage of 4,543; in 1910, 70 vessels, totalling 30,215 tons; and, in 1920, 140 vessels, with a total of 456,642 tons. During that time, too, there was erected at Nagasaki the first Japanese experiment tank, 494 ft. in length.

Historical Electrical Apparatus at the Smithsonian Institution.

Four interesting historical pieces of electrical apparatus have recently been presented to the United States National Museum at the Smithsonian Institution by the Westinghouse Electric and Manufacturing Company. The first of these is a Gaulard and Gibbs transformer, which was utilised by Westinghouse in developing alternating current transmission, while the second is a Tesla motor, the construction of which was based on the theory of the rotating magnetic field enunciated independently by himself and Ferraris in 1888. As was well known, passing a magnet over the surface of a sheet of copper caused the production of a force which tended to make the copper to move in the same direction as the magnet. Tesla discovered that such a moving magnetic field could be set up by an alternating current, and did not need a permanent magnet or one excited by direct-current. The third exhibit consists of a Cardew voltmeter, which was first designed in 1883 for measuring alternating current voltages. It consisted essentially of a thin wire, about 6 ft. long, which was stretched over a series of pulleys and was caused to expand by the current passing through it. A few years later an accident removed one of the most serious obstacles to the employment of alternating current by providing a means of accurately measuring the power supplied to a consumer. When a small spring fell into the mechanism of an arc lamp, it landed on the main magnet and Shallenberger noticed that it began to rotate. He realised that this rotation was caused by magnetic or electrical action, and thereupon quickly devised his original ampere-hour meter. This meter, which forms the fourth exhibit at the Smithsonian Institution, consists of a fixed primary coil in series with the mains. This induces currents in a stationary short-circuited secondary and in a disc which is set in continuous rotation. The speed of this disc is controlled by an air vane damper, so that it is proportional to the flow of current and the ampere or watt-hours are recorded by a dial train.

THE PUMPING OF GRANULAR SOLIDS IN FLUID SUSPENSION.

By HERBERT CHATLEY, D.Sc.(Eng.), M.Inst.C.E.

THE practice of pumping sub-divided solids in air or water streams is becoming increasingly important, but there is still much scope for improved efficiency. In their classical paper of 1924,* Cramp and Priestley outlined the main principles of the vertical pumping of grain. Possible efficiencies of 30 per cent. or thereabouts were indicated; whereas, in actual grain hoisting for ships, the power consumption is rarely less than 0·9 h.p. per hour per ton. For a pure lift of 50 ft., this represents an efficiency of only about 5 per cent.

The problem of horizontal transport is much more obscure than that of vertical lift, since the suspension is due to the vertical components of the secondary turbulent currents, but much light has been thrown on it by a paper by O'Brien and Folsom,† which has been confirmed in principle by de Frondeville and Siegfried.‡ The present writer, in 1932,§ indicated a method of computing the dilution which gives the minimum energy consumption per unit of solid transported, on the basis of an empiric rule for the variation of apparent pipe friction with concentration of solids in the mixture; and, in a recent paper,‖ he has pointed out the importance of the "sustentation function," which measures the energy consumed in keeping the particles in suspense, irrespective of transport.

It is the peculiar feature of the work of O'Brien and Folsom that it shows that the fluid friction, as such, of the mixture is not increased by the solids if the velocity is such that the grains are kept fully in turbulent suspension. On the face of it, this conclusion seems irrational, since the grains near the walls must collide with and rub against the walls, but it is partly a matter of expression. The turbulence being such that the grains are kept continually in suspension, the energy which is consumed in maintaining this condition may be considered, alternatively, as friction.

The elements of power consumption are then as follows:—

(1) Lifting the solid grains; for horizontal pipes, this will be zero.

(2) Accelerating the solid grains, *i.e.*, providing their kinetic energy; ideally, this might be recovered by retarding the flow towards the outlet, but such an arrangement could rarely be practicable.

(3) Sustaining the solid grains in the mixture, and overcoming their friction against the walls of the pipe.

(4) Accelerating the fluid, *i.e.*, providing its kinetic energy.

(5) Overcoming fluid friction.

(6) Compensating for loss of kinetic energy at bends, valves, etc.

Vertical Conveyance.—As a simple example, the case may be considered of a plain vertical 6-in. pipe, 50 ft. high, carrying up 30 lb. of grain per second (= 48 tons per hour), the grain having an effective terminal velocity in still air of 20 ft. per second, and the air velocity being 60 ft. per second. The effective vertical grain velocity is then (60 — 20) = 40 ft. per second. Taking the grain density (solid) as 75 lb. per cubic foot, the solid area of the grain stream is $30 \div (75 \times 40) = 0{\cdot}01$ sq. ft. As the sectional area of the pipe is about 0·2 sq. ft., the solid grain occupies only 5 per cent. of the pipe area.

The quantity of air passing (neglecting the small volume of solid) is $60 \times 0{\cdot}2 = 12$ cub. ft. per second; and the weight of this, neglecting changes of volume due to deviations of pressure, is about 0·96 lb. per second. Thus the volume ratio, air/solid is about 75; and the weight or mass ratio, solid/air is about 12½. Taking the six elements of power consumption in the order given above:—

The lifting power

$$= \frac{30 \times 50}{550} = 2{\cdot}77 \text{ h.p.};$$

The grain-accelerating power

$$= \frac{30 \times (60 - 20)^2}{64 \times 550} = 1{\cdot}36 \text{ h.p.};$$

The sustaining power

$$= \frac{0{\cdot}75 \times 50 \times 20}{550} = 1{\cdot}36 \text{ h.p.}$$

If the grain friction be included in this item, Cramp and Priestley indicate that it may increase this amount by 100 per cent. or even more. (This is the present writer's "sustentation function," and represents the energy per unit time required to restore the grains, which are continually falling with the terminal velocity in the fluid, to the same imaginary level. The weight of grain per foot of pipe is $0{\cdot}01 \times 75 = 0{\cdot}75$ lb.; and the total weight in the whole length of pipe is $0{\cdot}75 \times 50 = 37{\cdot}5$ lb. All this is falling in the air with a terminal velocity of 20 ft. per second, and deprives the air of corresponding momentum, which must be made up. Cramp and Priestley attack this factor by momentum methods which appear to be unnecessarily complex.)

The air-accelerating power

$$= \frac{0{\cdot}96 \times (60)^2}{64 \times 550} = 0{\cdot}1 \text{ h.p.}$$

(Cramp and Priestley consider this item to be negligible in most practical cases.)

The air-friction power, approximately,

$$= \frac{1}{100{,}000} \times \pi \times \tfrac{1}{2} \times 50 \times (60)^3 \div 550 = 0{\cdot}15 \text{ h.p.}$$

(The unknown condition of the pipe surface makes this item only approximate, but for low air velocities it is not important. The grain friction is referred to in connection with the sustaining power, above.)

The bend-resistance power is zero in this hypothetical case of a plain straight vertical pipe, but, in actual fact, there must be bends at both ends, and the power to overcome their resistance may easily be equal to that required to restore the full kinetic energy of the air, and possibly even that of the grain.

There is thus a total of 5·74 h.p. (excluding bends and grain friction), or an ideal efficiency of $2{\cdot}77 \div 5{\cdot}74 = 48$ per cent., which may easily be reduced to 30 per cent. by grain friction, and still more if the grain has to be re-accelerated at bends, inlets, etc. It is well known in pneumatic-conveyor practice that the effect of bends and other interferences with straight-line flow is enormous, and it goes without saying that they must be eliminated as much as possible.

It will be observed that items (2) and (3) are preponderant in this example, whereas items (4) and (5) are small. This will generally be the case unless the air velocities are high, and it is of interest, therefore, to consider what combination of (2) and (3) is most economical of energy. Item (2), in ft.-lb. per second, can be expressed as mass per second × (air velocity — terminal velocity)²/64; and item (3), in mass per second, can be reduced to $\frac{\text{terminal velocity} \times \text{lift}}{\text{air velocity} - \text{terminal velocity}}$. If now we write air velocity $v = c \times$ terminal velocity v_1, it can be shown by the calculus that the maximum and minimum conditions for the sum of these two items are given by the equation

$$c = \sqrt[3]{\frac{32\,h}{v_1^2}} + 1,$$

where h is the lift in feet.

Thus, if

$$h = 50, \text{ and } v_1 = 20, \; c = \sqrt[3]{\frac{1{,}600}{400}} + 1 = 2{\cdot}59;$$

making the best air velocity, in this case, 51·8 ft. per second.

Horizontal Conveyance.—Turning now to the question of horizontal conveyance under pressure, forced or induced, or (in the case of hydraulic conveyance) in downward-sloping pipes, it is clear that all the items except (1) still remain valid. Item (1) itself appears as a negative in the case of downward hydraulic flow. The difference between the fluid velocity along the pipe and the terminal velocity, however, is no longer the effective factor in suspending the grains, as the two are at right angles. If the pipe is horizontal, or nearly so, the only currents capable of sustaining the grains are the vertical components of turbulence. According to O'Brien and Folsom, for full turbulence, these secondary currents have vertical components equal to about 15 per cent. of the magnitude of the mean axial velocity of the fluid in the pipe; so that the whole solid contents cannot be kept in suspension unless the axial velocity is six or seven times the terminal velocity. In such a case, the mean velocity of the grains along the pipe is reputed to be nearly equal to the fluid velocity. How far this is a true picture of affairs remains somewhat doubtful, but it appears to conform to observation.

If these ideas are applied to the case discussed above, excepting the lift—that is, the carriage of 30 lb. of grain per second in a 6-in. pipe—we get the following conditions in 50 ft. of horizontal pipe.

(2) Accelerating the grains:

$$\frac{30 \times (130)^2}{64 \times 550} = 14{\cdot}4 \text{ h.p.}$$

(This item is not dependent on the length of the pipe, so that it becomes of relatively less significance for long pipes; $130 = 6\tfrac{1}{2} \times 20$, the necessary axial velocity for sustentation.)

(3) Sustaining the grains: the area of pipe occupied by solids is now very small, and is equal to

$$\frac{30}{75 \times 130} = 0{\cdot}003 \text{ sq. ft.}$$

As the pipe area is about 0·2 sq. ft., this is only 1½ per cent. of the section of the pipe. The weight of grain in the whole pipe is

$$0{\cdot}003 \times 75 \times 50 = 11{\cdot}25 \text{ lb.}$$

This having a terminal velocity of 20 ft. per second, the power required to sustain it is

$$\frac{11{\cdot}25 \times 20}{550} = 0{\cdot}41 \text{ h.p.}$$

Wood and Bailey* attacked the problem by investigating the generation of momentum in the particles by the air stream. They give the ultimate horizontal grain velocity as

$$v_f = v\left\{\frac{k_1 \pm \sqrt{k_1 k_2}}{k_1 - k_2}\right\},$$

where k_1 and k_2 are the resistance coefficients of the grain with the air and the walls, respectively. Obviously, the ultimate grain velocity does not differ greatly from v, the air velocity.

(4) Air-accelerating power: the air volume is $0{\cdot}2 \times 130 = 26$ cub. ft. per second, and the air weighs 2·08 lb. The power then is

$$\frac{2{\cdot}08 \times (130)^2}{64 \times 550} = 0{\cdot}99 \text{ h.p.}$$

(5) Air friction power: since the velocity is 130 ft. per second, as against 60 ft. per second in the vertical example, and the length of pipe is the same, the friction power is increased in the ratio

$$\left(\frac{130}{60}\right)^3 = 10{\cdot}17 \text{ times};$$

and the power becomes

$$0{\cdot}15 \times 10{\cdot}17 = 1{\cdot}525 \text{ h.p.}$$

(6) Bend resistance power: this will be increased in the ratio of $\left(\frac{130}{60}\right)^2$, but for the present purpose it will be neglected.

Thus the total is 17·32 h.p., of which the major part is in the acceleration of the grains to the high velocity. This corresponds to about 0·36 h.p.-hour per ton. To carry the same quantity of solids through the same length of pipe, therefore, may

---

* "Pneumatic Grain Elevators," by Professor W. Cramp and A. Priestley, *The Engineer*, vol. 137, page 89 (1924); and Professor W. Cramp, *Jl. Royal Soc. of Arts*, vol. 69, page 283 (1920-21). See ENGINEERING, vol. 111, page 205 (1921).

† "The Transportation of Sand in Pipe Lines," by Professors M. P. O'Brien and R. G. Folsom, *University of California Engineering Publications*, vol. 3, page 343 (1937).

‡ "Dragage et Refoulement des Déblais à l'Etat de Mixtures," by P. Durepaire, *Ann. Ponts et Chaussées*, vol. i part II (1939).

§ "Energy Considerations in Dredging," *Inst. C.E., Selected Paper* No. 125 (1932).

‖ "Terminal Velocities," *Jl. Junior Inst. Eng.*, vol. 50, page 81 (1939); see ENGINEERING, page 6, *ante*.

* "The Horizontal Carriage of Granular Material by an Injector-Driven Air Stream," by S. A. Wood and A. Bailey, *Proc. I. Mech. E.*, vol. 142, page 149 (1939).

require, in this case, three times as much energy when the pipe is horizontal as when it is vertical, because of the higher air velocity necessary to sustain the solids in the horizontal pipe.

Combined Horizontal and Vertical Pipe.—The two cannot be added together for a combined horizontal and vertical pipe because the velocity requirements are different in the two pipes, and the acceleration items need to be reckoned only once. This peculiarity of greater velocity being needed in the horizontal pipe, is possibly the major reason for the low observed efficiency of pneumatic transport, which generally has some horizontal, or at least inclined, stretches of pipe.

Hydraulic Conveyance.—In the case of hydraulic conveyance in pipes, the buoyancy of the particles reduces the energy of sustentation in the ratio of the buoyant weight to the gross weight. Thus, if material with a density of 75 lb. per cub. ft. is considered, the buoyant density is only (75 — 62·5) = 12·5 lb. per cub. ft. The terminal velocities, of course, are much smaller in water than in air. For similar shapes and similar Reynolds numbers, since water is 800 times as dense as air, the terminal velocity ratio (water/air) is

$$\sqrt{\frac{\text{buoyant density}}{800 \times \text{gross density}}}.$$

If the gross density is 75 lb. per cubic foot, this is $\frac{1}{6\cdot9}$; or, for sand (density, say, 162·5 lb. per cubic foot), it is $\frac{1}{9\cdot5}$. Thus, for the same grains as before, in the same horizontal pipe, and for the same length, the terminal velocity is only 20 ÷ 69 = 0·3 ft. per second; and the necessary water velocity is only about 2 ft. per second. While, at the same velocity, the fluid friction is nearly 800 times greater than in air, the reduction of the velocity from 130 ft. per second to 2 ft. per second more than cancels this increase, so that hydraulic conveyance is much more economical than pneumatic conveyance for materials which are not injured by wetting.

The figures given indicate that the present low efficiencies are largely attributable to the effects of bends and inlets, or the incorrect proportioning of fluid and solid. When the solids are not sustained in the stream, they can only be propelled horizontally by rolling, in which the energy consumption is much greater. The underlying principles must also apply to natural streams conveying sediment; but in this case the problem is complicated by the unstable walls of the channel, although there is then a close resemblance to the pipe which is partially filled with unsustained material.

METALS AS ENGINEERING MATERIALS.—II.

THE fact that progress in engineering materials had been closely linked with improvements in testing methods constituted the main theme of the second Cantor Lecture on "Metals as Engineering Materials," delivered by Dr. C. H. Desch, F.R.S., on the afternoon of February 5, at the Royal Society of Arts, Adelphi, London, W.C.2. In the course of his opening remarks, he stated that the hope had sometimes been expressed that a relation might be found between the mechanical properties of a metal subjected to working stresses, and definite physical properties, capable of exact measurement. Such a solution of the problem was unlikely. The properties, both physical and mechanical, of single crystals were the object of exact study by a great number of methods which usefully supplemented one another, but it was not yet possible to deduce from them the properties of an aggregate of similar crystals, and even if this were done, there would still be the difficulty of the heterogeneous texture of actual materials. One set of constants which could be determined physically was, however, of importance for engineering purposes, namely, the elastic moduli. Young's modulus, which was usually determined from the slope of the load-extension curve in the tensile test, could also be measured by acoustic methods. It was closely related to the atomic volume, but, as at the ordinary testing temperatures the metals were very unequally removed from their melting points, the temperature had to be brought into the relation. If the value $\frac{T}{V^2}$ (T being the temperature of melting on the absolute scale and V the atomic volume) were plotted against the values of Young's modulus, the points lay near to a straight line, with the exception of that for tungsten, which had the highest known modulus. A few typical values of Young's modulus are given in Table I.

TABLE I.

Metal.	Young's Modulus.	
	Kg. per sq. mm.	Lb. per sq. in.
Tungsten	42×10^3	60×10^6
Beryllium	36×10^3	51×10^6
Iron and Steel ..	21×10^3	30×10^6
Copper	$12{\cdot}6 \times 10^3$	18×10^6
Brass	$10{\cdot}8 \times 10^3$	$15{\cdot}4 \times 10^6$
Aluminium	$7{\cdot}3 \times 10^3$	$10{\cdot}4 \times 10^6$
Magnesium	$4{\cdot}5 \times 10^3$	$6{\cdot}4 \times 10^6$
Lead	$1{\cdot}8 \times 10^3$	$2{\cdot}5 \times 10^6$

The high position of the light metal beryllium was very noticeable, but, unfortunately, the other properties of the metal were such that it had not yet been found possible to take advantage of the high modulus for constructional purposes. The first fact to be noted concerning the modulus of elasticity was that it could not, like most of the other mechanical properties of a metal, be improved by alloying or by heat treatment. Each metal had a definite elastic modulus in the polycrystalline state, which only varied slightly with the amount of impurities present. This substantial invariability of the modulus led to a certain limitation in the use of new materials. The light metals had a low modulus. If, therefore, steel were replaced by a light alloy of equal tensile strength, and advantage were taken of this to reduce the mass of a member in proportion, the modulus being only one-third as great, it might prove to be insufficiently stiff, and "whipping" and other troubles might arise. This difficulty could not be overcome by increasing the strength still further and the design must be altered to suit the new material, or the member must be made thicker than the calculated strength would indicate.

Great importance had been attached to the determination of the "elastic limit." The term was a misleading one, and it was unfortunate that it was so widely used. The more delicate the extensometer employed in testing, the lower, as a rule, was the value found for the elastic limit. On the other hand, the device of the "proof stress" was sound and theoretically unobjectionable. The tensile test was the most important and widely used in the testing of materials, but the data which it furnished were not physical constants. The ultimate-stress value was not a measure of the cohesion, except perhaps in entirely brittle materials, such as glass or white cast iron, which broke without any previous plastic deformation. In the case of ductile materials, plastic deformation took place during the test, and failure occurred by shear rather than by a simple pulling asunder of the two adjoining parts. During the last stages of the test, the load had been acting on a reduced cross-sectional area, so that the maximum which appeared on the load-extension curve was only an apparent one, and did not represent a maximum stress on unit area. A curve showing the relation between true stress and true area of section rose steadily, being sometimes linear over a considerable range, but often rising more rapidly towards the end. Such a curve was not easy to construct, as it required a determination of the diameter at each stage of the test, as well as of the load. For this reason, little work had been done on curves taken in this manner, and a device enabling them to be determined without too much trouble would be of great use. A curve of this kind gave important information; the slope of the linear portion, which came after plastic yielding had set in, represented the "work-hardening capacity" of the material, a factor of great technological significance.

The notched-bar impact test had been designed to determine whether a material was likely to break in a brittle fashion under shock, especially under conditions of localised stress. The test, although very valuable, failed in one respect. A strong but hard material, with little capacity for plastic deformation, might give a satisfactory result with the comparatively blunt notch employed, and yet be liable to fail suddenly if an intense local concentration of stress should present itself, as at a hair-line crack. There were instances in which it had been found advisable to temper some high-tensile alloy-steel forgings at a higher temperature than that normally used, thereby sacrificing some tensile strength, in order to guard against sudden and dangerous failure from the spread of a minute crack, however caused.

Fatigue testing played an increasing part in the examination of modern engineering materials. Supposing a true fatigue limit of materials to exist, however, it was important to note that it bore no relation to the limit of proportionality or to the yield point of the material. On the other hand, for most metals, it bore a fairly close relation to the tensile strength, a factor 0·5 being commonly used for steels, while, for light alloys, it might be as low as 0·35. To a far greater extent than for static stress, studies of failure under alternating stress involved a full examination of the microscopic changes which preceded and accompanied the formation of a crack. X-ray studies had given much information, and the work of Gough and Wood, in particular, had shown the close similarity between the changes under static and alternating loading, but to interpret failure exclusively in terms of the changes in X-ray patterns was to overlook the evidence from the microscope that the deformation in both conditions, and especially in fatigue, was highly localised, and that while one region was extensively broken down, and progressively so as the process went on, neighbouring regions underwent little distortion. It was in these highly distorted zones that cracks started, and it was there that recrystallisation first occurred if the deformation were interrupted and the specimen annealed. These effects had been well studied in cupro-nickel which had the property of etching clearly even when heavily cold-worked.

Much effort had been expended in devising suitable tests for resistance to creep. The chief difficulty was caused by the fact that the metal underwent changes of structure under the combined influence of prolonged heating and stress, so that the material which was examined at the end of the test was different from that at the beginning. In spite of the great number of investigations carried out on the subject of creep, different workers had used such different conditions of test that it was difficult to compare results. It was remarkable, for instance, that it could not be said with certainty, as yet, whether the effect of increasing the carbon within normal limits strengthened or weakened a steel in creep. It had been found difficult to secure steels otherwise quite similar and only differing in carbon content. Resistance to creep, however, was increased by the addition of certain alloying elements, molybdenum being specially useful in this respect. Alloying elements in steels could affect the resistance to creep in several different ways. The strengthening of the ferrite was one of these, but the action of the added element in accelerating or retarding spheroidisation of the carbide, and in hastening or hindering recrystallisation, was equally important. The effects on resistance to steam corrosion had also to be taken into account, especially where working was intermittent and cracking of the oxide film might occur.

Most metals used in engineering were exposed in some degree to chemical attack, by the atmosphere, by natural waters, or by more active chemical substances. Even air could produce corrosion-fatigue in steels and other metals, so that for an absolute standard of comparison fatigue experiments had to be made in a vacuum apparatus. In scientific research work, X-ray methods were growing in importance; they were of the greatest assistance in the study of alloy systems and were also used as a means of investigating the nature of such processes as hardening by cold work. Engineers and metallurgists, however, were anxiously seeking for a means of determining internal stresses in a casting or forging by some non-destructive method.

Much had been done on the production, and in connection with the more difficult interpretation, of X-ray evidence for the amount and distribution of such stresses, but a good deal of ground would have to be covered before this method could become a standard means of controlling engineering materials.

THE LATE PROFESSOR F. P. PURVIS.

WE have learned with regret of the death of the veteran naval architect, Professor Frank Prior Purvis, which took place at Seaford on February 20, within a few weeks of his 90th birthday. The son of a doctor, Purvis was born on April 18, 1850, and received his early education at Blackheath School. In 1867, on leaving Blackheath, he entered the famous Royal School of Naval Architecture and Marine Engineering at South Kensington, of which he became a Fellow in 1871. He gained a Whitworth Exhibition in 1868, and a Scholarship in the following year. He obtained practical shipbuilding experience in the Royal Dockyards, being stationed at Deptford for a short time in 1868, and at Chatham from the latter part of that year until 1870. In 1871, he completed his pupilage on the Clyde with the firm of Robert Napier and Sons, leaving them in that year to join the staff of Sir Edward Reed, who, in 1870, had resigned his post of Chief Constructor at the Admiralty. On Reed's behalf, Purvis superintended the construction of the German ironclads Kaiser and Deutschland.

In 1871 he became assistant to William Froude at his Admiralty tank at Torquay, and for six years was engaged on the epoch-making experiments made there. From Torquay he went to the Fairfield Shipbuilding Company under Sir William Pearce, and in 1879 superintended the construction of docks at Dortmund and Amsterdam. Purvis' next appointment was with Messrs. William Denny and Brothers. William Denny, who had greatly admired Froude's work, decided to build an experiment tank at Dumbarton. It was constructed under the supervision of Purvis, who remained as head of Messrs. Denny's scientific staff for ten years. Froude's tank was 250 ft. long, 33 ft. wide, and had a maximum depth of 10 ft. The tank at Dumbarton was 300 ft. long, 22 ft. wide and 10 ft. deep. The first model was tried in it in 1883, and it proved of great value in the design of the channel steamers which the firm was then beginning to construct.

From Dumbarton, Purvis went, in 1889, to Port Glasgow, as shipbuilding partner in the firm of Blackwood and Gordon, with whom he was associated until 1899. Two years later he was selected to succeed Professor P. A. Hillhouse as professor of naval architecture in the Imperial University at Tokyo, where he remained until his retirement 16 years later. He became a member of the Institution of Naval Architects in 1882, and of the Institution of Civil Engineers in 1905, and was a member also of the Institution of Engineers and Shipbuilders in Scotland and of the Japanese Society of Naval Architects. His first published paper, on "The Effect of Depth Upon the Strength of a Girder to Resist Bending Strains," was presented before the Institution of Naval Architects in 1878. He delivered another paper before the same Institution in 1885, on "The Stowage of Steamships." With Mr. B. Kinderman, in 1883, he contributed a paper "On Approximations to Curves of Stability" to the Institution of Engineers and Shipbuilders in Scotland. His services to Japanese shipbuilding were recognised by the conferment of the Order of the Rising Sun and the Order of the Sacred Treasure, while the Imperial University made him Doctor of Engineering, *honoris causa*.

TRIGONOMETRICAL SLIDE RULES.—The use of tables of trigonometric ratios, though long-established and widespread, is admittedly liable to error from careless reading, and the tables themselves are often contained in books relating to other matters. In order to prevent error and ensure compactness, the slide-scale form has been adopted, that is, as far as it concerns a fixed and a sliding element. The fixed element in the new rule consists of a glazed card case, on which are drawn various trigonometrical figures. Windows at appropriate parts of the several triangles display the value of the sines, tangents, etc., of a particular angle chosen by movement of the sliding element, also of glazed cardboard. As only one set of figures is visible at a time, errors should be impossible, while the rule is certainly very compact, giving all ratios for angles from 0 deg. to 90 deg. in steps of 10 minutes, and to five places of decimals. The rule is made by Messrs. Omaro (England), Limited, 104, High Holborn, London, W.C.1. A companion rule deals with different values of arcs, segments, chords, etc., and we understand that it is proposed to continue the series to deal with such things as threads, sizes and weights of plates and bars, etc.

EXPERIENCES WITH HIGH-TEMPERATURE HIGH-PRESSURE STATIONS.

(*Continued from page* 211).

A FURTHER section of our abstracts of the papers dealing with power-station operation, presented at the annual meeting of the American Society of Mechanical Engineers at Philadelphia in December, 1939, appears below.

SUPERPOSED INSTALLATION AT OMAHA STATION OF MESSRS. NEBRASKA POWER COMPANY.
By LOUIS ELLIOTT.

Information was presented two years ago before the Society concerning the high-pressure high-temperature superposed extension at the Omaha Station of Messrs. The Nebraska Power Company. The present statement covers the period from initial operation in February, 1937, to May, 1939, and includes operating data and experience in addition to or differing from that detailed in the previous paper.

In brief, the extension includes one 10,000-kW 0·8-power factor turbo-generator, designed for 1,200-lb., 900 deg. F. operation, and one 265,000-lb. per hour bent-tube boiler with economiser and regenerative air heater, fired by a 570-sq. ft. travelling-grate stoker. The high-pressure turbine is superposed on a 15,000-kW 200-lb. condensing unit, with a non-automatic reducing and de-superheating station discharging to a 325-lb. header. Division of load between high-pressure and topped units is determined by maintenance of constant back pressure on the former. The station is operated normally with at least one 325-lb. turbine and one or more boilers on the line, in addition to the superposed combination.

Operating time of boiler and turbine to May 1, 1939, has aggregated about 15,000 hours, equivalent to 78 per cent. of elapsed time since initial service. Availability (practically equal to "demand availability") of the high-pressure turbine unit for the entire period has been 82 per cent., and for the last 7,300 hours, since latest overhaul, 94 per cent. The unit was opened up in February, 1938; the next overhaul was scheduled for February, 1940. High-pressure boiler availability has been 87 per cent. for the entire period, and 94 per cent. since the latest general overhaul. Generation by the high-pressure unit has been at 78 per cent. unit output factor (based on 10,000-kW rating) for the entire service period. Operation of the topping combination has been practically continuous since the early part of this year, and reliability is considered as substantially on a par with that of the 325-lb. section of the plant.

Load on the combined unit is determined by consideration of overall station costs, of service reliability, and of certain operating and maintenance difficulties experienced. As examples, loading is influenced by economy characteristics of the 325-lb. units operated, by the formation of deposits on the blading of the 1,200-lb. and 200-lb. turbines, and on the tubes of the cross-over heater, and by slagging of boiler-heating surfaces.

High-Pressure Turbine.—Reduction of turbine capacity from blade deposits was experienced prior to the February, 1938, overhaul, at which time blading was cleaned by blasting with fly ash because silica content and temperature conditions prevented removal by washing. Subsequently, boiler-water concentrations were reduced, and leakage of the low-pressure unit condenser is now checked regularly; stage pressures and load tests now indicate no appreciable scaling of blading, so that further ash-blasting may not be necessary. The turbine unit originally showed some vibration, but with adjustments, made from time to time, conditions are now much improved and are quite tolerable.

As at first installed, the turbine water rate was 2 per cent. to 3 per cent. high at lighter loads, caused, in part, by excessive high-pressure packing clearances, but largely by turbulence of steam in the space between the first-stage wheel exit and smaller diameter nozzles of the second stage. A dam or baffle was installed in the first-stage shell space, extending from the inside of the shell to the rotor and attached to the second-stage diaphragm and to the inside of the upper half of the casing. This improvement eliminated much of the loss and permitted the turbine to give its expected performance. No automatic devices have been installed, or other provision made, to protect against overheating of the turbine with loss of load. The smaller turbines are less vulnerable in this respect than the larger.

Starting-up procedure has been modified as compared with the method reported two years ago. The 200-lb. turbine is now started first, taking steam through the 325-lb. to 200-lb. reducing valve. The exhaust valve of the high-pressure turbine is also opened to admit 200-lb. steam to the turbine casing. The high-pressure boiler is brought up to 600 lb. or 800 lb. pressure, passing 75,000 lb. to 100,000 lb. of steam per hour through the 1,200-lb. to 325-lb. reducing valve. The high-pressure turbine is then started, exhausting to the 200-lb. turbine. As the load is picked up, the 1,200-lb. to 325-lb. reducing valve is closed, and the boiler pressure is raised to 1,200 lb. This method obviates loss of steam to the atmosphere, inherent in the original starting method. Starts and stops have been relatively infrequent—only as occasioned by maintenance requirements.

High-Pressure Boiler.—There is little occasion to make rapid changes in load on the combined unit, and the boiler output is maintained steady, except as the daily load curve calls for adjustment at certain hours. Deficiency in total steam temperature persists, correction having been delayed. On account of this temperature condition, there has been no need for control of steam temperature, for which a manually-operated by-pass gas damper is provided.

Slagging of boiler-unit heating surfaces must be fought continually, the Kansas coal burned having relatively high sulphur content and low ash-softening temperature; samples show initial deformation at 1,850 deg. F. and a fluid condition at 2,100 deg. F. or below. Because of these ash characteristics, difficulties of cleaning boiler and air-heater surfaces increase rapidly as maximum boiler capacity is approached. The boiler is now normally operated during the day period at an output of approximately 225,000 lb. per hour, as slagging difficulties increase above 230,000-lb. to 240,000-lb. per hour output. It requires 14 man-hours per day for cleaning of the heat-transfer surfaces.

No circulation troubles have been experienced in boiler or furnace walls or arches, and the travelling-grate stoker has developed no operating or maintenance difficulties, notwithstanding its great size. Boiler water is conditioned to maintain an average *p*H value of 10·7, while keeping total solids at 250 parts per million and total alkalinity at 75 parts to 100 parts per million. A ratio of 0·5 between sulphates and carbonates is normal.

Air-Heaters and Feed Pumps.—Corrosion and plugging of the air heater at the top of the inlet side of the rotating element results from the sulphur and moisture content of coal. This necessitated installation of a by-pass around the air heater to permit cleaning. The upper 4-in. portion of the regenerative surface has been modified and is now made up of elements with corrugations designed to give a freer gas travel, and bound together in groups so as to permit ready removal of a corroded or fouled surface and substitution of new or cleaned sections. The shaft of one of the 3,600-r.p.m. steam-driven feed pumps failed completely. The majority of opinion is that this resulted from imperfections in shaft material.

(*To be continued*).

ULTRA-RAPID VOLTAGE REGULATOR.

WHEN a heavy load is put on or taken off an electrical generator, it is important that the consequent variation of pressure should be a minimum and should persist for as short a time as possible. The rapid regulation necessary to fulfil these conditions is, however, rendered difficult of achievement, owing to the magnetic inertia of the generator and its exciter, which makes it impossible suddenly to alter their fields. To overcome this difficulty, the Oerlikon Company, whose London address is Victoria House, Southampton-row, W.C.I, have designed a composite regulator. This consists of their standard quick-acting regulator, which is arranged to deal with small variations in pressure, and of an over-regulation device, which comes into action when the pressure differs from its correct value by about $\pm$ 2 per cent. The period during which this over-regulation is in action depends upon the amount by which the pressure differs from its correct value, and it is cut-out automatically before this value is attained.

A general view of the regulator is given in Fig. 1, opposite, and its method of operation can be followed from the diagram reproduced in Fig. 2. The main regulator consists of a measuring system *a*, which is constructed on the Ferraris principle, and, as will be seen, is connected across the pressure which is to be regulated. It comprises a drum on which are a main and auxiliary winding so connected that the currents in them have a phase displacement of 90 deg., this ensuring maximum torque and absence from vibration. The movement of this drum is controlled by springs, which are so arranged that the friction on the bearings is reduced to a minimum. The drum is of iron, and there is no inner core, the result of the construction being that a torque of about 1,000 gm.-cm. can be developed with an electrical loading of 20 volt-amperes. Damping is effected by the dashpot *b*, and the return spring *c*, while the regulating system consists of a rolling sector *d*, which is linked to the drum spindle and follows its angular displacement. A resistance spiral of the regulating resistance is connected to each segment of

ULTRA-RAPID VOLTAGE REGULATOR.

THE OERLIKON COMPANY, OERLIKON, SWITZERLAND.

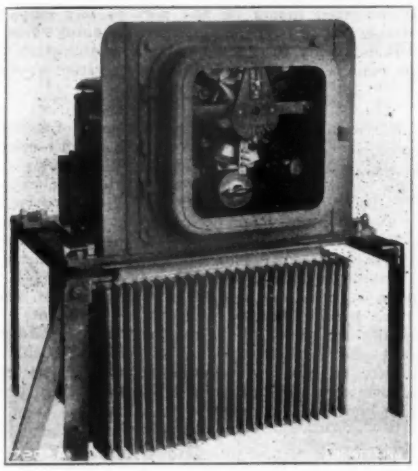
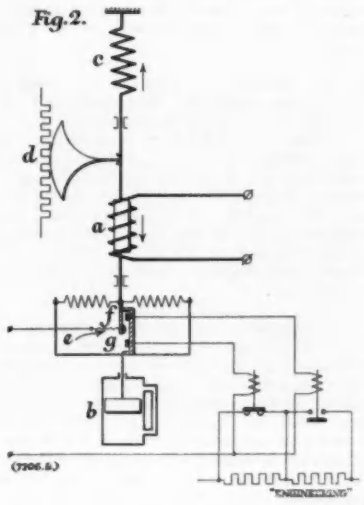
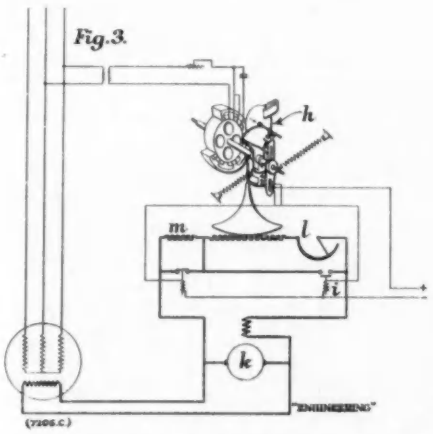
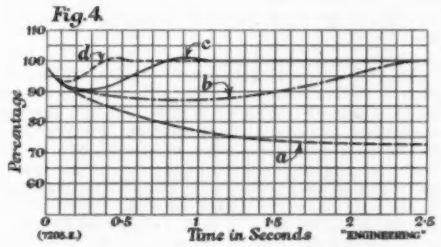


FIG. 1.







the contact path, so that as the sector moves the segments are short-circuited. The over-regulation device consists of a moving contact *e* and two pins *f* and *g*. In the event of a rise in pressure, contact takes place between *e* and *g*, while similarly in the event of a drop in pressure it occurs between *e* and *f*.

Dealing with the operation of this ultra-pressure regulating device in more detail, reference may be made to Fig. 3, in which the regulator, as already described, is shown diagrammatically at *h*. Assuming that the pressure is to be maintained at 100 volts, when it falls below 98 volts contacts *e* and *f* close and close the switching contactor *i*. As a result, all the resistances in the shunt circuit of the exciter *k*, that is to say, the regulating resistance and the resistance of the hand-operated field rheostat *l* in series with it, are short-circuited. Maximum over-regulation is, therefore, applied until the pressure has risen to 98 volts, when regulation is again taken over by the quick-acting regulator. In the case of a rise in pressure over 102 volts, regulation is effected in a similar way, except that the resistance *m* is inserted in the shunt circuit by the contactor *i*.

Oscillograms taken on a 2,500-kW generator with a normal exciter and a load consisting of an induction motor, the starting current of which was equal to about half the rated current of the generator, show that with the ordinary quick-acting regulator normal pressure was reached in about 2·6 seconds after the load had been thrown on, while with a Tirrill regulator and an ultra-rapid regulator it was attained within 0·8 second. This is shown in Fig. 4, where curve *a* indicates what happens when there is no regulator, and curves *b* and *c* illustrate the effects of an ordinary quick-acting regulator and an ultra-rapid regulator, respectively. It may be pointed out that the tests in question were carried out with an exciter of standard dimensions. If, however, the exciter had been over-dimensioned to the extent of 50 per cent., the regulation time could have been still further reduced, as shown in curve *d*.

In a modified form of regulator the sector and contact path are replaced by an oil servo-motor, the sensitiveness of which is said to be as high as $\pm 0 \cdot 3$ per cent. The torque of the servo-motor, which actuates the 400 step regulating resistance, is 25·2 lb.-ft., and this is ample for the purpose. This arrangement, it is claimed, is particularly useful where over-regulation is applied separately through contactors and auxiliary excitation, or over-compounding coils supplied from a different source of current. The current can be varied in these additional exciter circuits much more rapidly than in ordinary exciter coils, so that higher regulating speeds are obtained. As these coils are not permanently in circuit, there are no additional power losses.

THE UNWIN MEMORIAL FUND.

WAR-TIME conditions having made it impracticable to hold a meeting of subscribers to the above Fund to commemorate the work of the late Dr. W. C. Unwin, F.R.S., the Unwin Memorial Committee has been unable to report the results of its activities in this way. A report has been prepared, however, and, at the request of Sir Alfred Chatterton, C.I.E., we have pleasure in reproducing it below.

The Unwin Memorial Committee was constituted in February, 1935, at a meeting held at the Institution of Civil Engineers, at which were represented the leading technical institutions, the colleges with which he had been connected, former students and others interested in commemorating the life and work of the late Dr. W. C. Unwin, F.R.S. It was decided that the principal objects to be aimed at were the raising of a sum sufficient to enhance to a more useful scale the value of a small existing Unwin Scholarship at the City and Guilds College and the publication of a memoir, based on the special number of *The Central*, issued after Dr. Unwin's death. An Executive Committee was appointed under the chairmanship of Sir Alfred Chatterton, C.I.E., who was also chairman of the main Memorial Committee. With the assistance of the Institutions of Civil Engineers, Mechanical Engineers, Electrical Engineers and Naval Architects, copies of an appeal were circulated to the members of these institutions, and the Executive Committee took various other steps to raise the required fund.

In February, 1938, this Committee was able to report to the Memorial Committee that the objects aimed at had been achieved. The latter, thereupon, at a meeting held in the same month, decided that the fund should be made over in due course to the City and Guilds of London Institute, to be held in trust by that body to endow a scholarship at the City and Guilds College for a third-year student of that College desirous of continuing his studies for a fourth year.

The Committee wish to record their grateful thanks to past students of Dr. Unwin and all others who have made this undertaking such a success. The amount originally asked for was 2,500*l.*, and the gross amount received to date is 2,949*l.* 12*s.* 8*d.*, of which 2,703*l.* 16*s.* 9*d.* was in the form of direct subscriptions. Special thanks are given to those who generously subscribed large sums in recognition of Dr. Unwin's valuable contributions to engineering practice. It is felt that the cordial expressions of support which accompanied these gifts afford ample justification of the task which the Memorial Committee set itself. Sums of 100*l.* and over were received from: Balfour, Beattie and Co., Ltd.; British Aluminium Co., Ltd.; The British Electrical and Allied Manufacturers Association, Inc.; British Oxygen Co., Ltd.; Cement Marketing Co., Ltd.; Thos. Firth and John Brown, Ltd.; The Gas Light and Coke Co.; the late Sir J. Purser Griffith; Sir Robert A. Hadfield, Bart.; the Rt. Hon. Viscount Nuffield; Ruston and Hornsby, Ltd.; and Vickers-Armstrongs Ltd.

Donors of sums between 20*l.* and 100*l.* are W. H. Allen, Sons and Co., Ltd.; Anglo-Iranian Oil Co., Ltd.; the late Sir John A. F. Aspinall; Babcock and Wilcox, Ltd.; Ivor Braby, Esq.; the British Compressed Air Society; the City and Guilds of London Institute; the Worshipful Company of Clothworkers; Messrs. Coode, Wilson, Mitchell and Vaughan-Lee; the late Sir Archibald Denny, Bart.; the late Sir John Dewrance; Sir Alexander Gibb; Glenfield and Kennedy, Ltd.; Alfred Herbert, Ltd.; Messrs. C. S. Meik and Halcrow; Messrs. Mott, Hay and Anderson; Bernard Price, Esq.; William Reavell, Esq.; Messrs. Rendel, Palmer and Tritton; the Tunnel Portland Cement Co., Ltd.; the Rt. Hon. Viscount Wakefield; the Rt. Hon. Lord Weir; and Yarrow and Co., Ltd. The number of subscribers of smaller amounts is 251. The Committee appreciate that in many cases the sums given by smaller subscribers have meant as much to them as have the larger gifts from other sources.

On the inauguration of the Fund, the American Society of Civil Engineers, the American Society of Mechanical Engineers and the Engineering Institute of Canada co-operated by forming committees to assist. These committees were merged subsequently into one body. This Committee ultimately sent to the Executive Committee in London 100*l.* as the contribution of engineers in Canada and the United States. The Committee greatly value this contribution, particularly so as the conditions prevailing on the North American continent then were not at all favourable. It is a great tribute to the lasting character of Unwin's work.

The memoir, *The Life and Work of William Cawthorne Unwin*, written for the Committee by Mr. E. G. Walker, F.C.G.I., M.Inst.C.E., is an octavo volume of 254 pages, with 16 illustrations, and was published originally by the Committee with a view to reducing expense. Owing to changes which took place subsequently in the arrangements of the executive, arrangements have now been made for the distribution of the memoir to be undertaken by Messrs. George Allen and Unwin, Ltd., 40, Museum-street, London, W.C.1, who are now dealing entirely with the sale of the book. It is unfortunate that the outbreak of war followed in point of time very shortly after the printing of the book; this hampered considerably the efforts to give it the publicity that it would have had under more normal conditions. It is hoped, however, that ultimately sales will prove sufficient to defray, at least, the greater part of the cost of the volume. In any case, there is every probability that, after deducting all legal and other expenses, the amount available for the endowment will exceed the 2,500*l.* originally aimed at.

The Committee gives cordial thanks to Mr. G. A. Hicks for his work as Honorary Secretary and for his services in connection with the printing and publication of the memoir, and to Mr. E. C. Walker, who not only undertook voluntarily the considerable work involved in the writing of the biography, but is also the Honorary Treasurer of the Fund. The Committee also records its appreciation of the work of the late Mr. John Severs, who acted as Joint Honorary Secretary until prevented by illness from continuing the work.

For the Unwin Memorial Committee,
(Signed) A. CHATTERTON,
Chairman.

THE INSTITUTE OF EXPORT.—At the recent annual general meeting of the Institute of Export, 11, Aldwych, London, W.C.2, Sir Patrick Hannon, M.P., was unanimously re-elected President for the second consecutive year. Mr. R. J. Turner was re-elected chairman and Mr. G. T. MacEwan vice-chairman of the Council, while Mr. N. R. Crute was elected treasurer in succession to Mr. T. H. Thatcher.

LABOUR NOTES.

THE trade unions which have members employed in railway workshops have accepted the offer of the railway companies of a 5*s.* per week wages increase for men, with proportionate advances for juveniles. At an earlier meeting of the Railway Shopmen's Council, on which the unions and the companies have equal representation, the companies, it is understood, made an offer of a 4*s.* a week flat-rate increase for men, corresponding to the offer accepted by the traffic-grade unions and the railway clerks. The shopmen's representatives, however, declined to accept it, pointing out that the employers had offered to men in the engineering industry an increase of 5*s.* per week. After further discussions, the companies increased their offer to 5*s.* a week, and the amended proposal was accepted by the representatives of the union at a meeting in York last week. The increase is payable as from January 1.

At a meeting in York on the same day, the unions affiliated to the Confederation of Shipbuilding and Engineering Trades accepted the offer of the Shipbuilding Employers' Federation to increase the wages of shipyard workers by 5*s.* a week for adults, with proportionate advances for apprentices and youths. This decision, no doubt, applies to the similar offer made to the Confederation by the Engineering and Allied Employers' National Federation.

The Ministry of Labour Gazette states that among insured persons between the ages of 16 and 64, the percentage unemployed in Great Britain and Northern Ireland at January 15 was 10·2, as compared with 9·1 at December 11, 1939, and 14·0 at January 16, 1939. For persons insured under the general scheme, the corresponding percentages were 10·2 at January 15, 9·1 at December 11, 1939, and 14·2 at January 16, 1939. For persons within the agricultural scheme, the percentages were 9·7, 7·4 and 11·2, respectively.

At January 15, there were 1,219,503 persons on the registers of Employment Exchanges in Great Britain who were out of a situation. This was 48,705 more than at December 11, 1939, but 374,928 less than at January 16, 1939. There were registered as unemployed in Great Britain 249,723 persons who were on short time or otherwise temporarily suspended from work. This was 106,658 more than at December 11, 1939, but 129,304 less than at January 16, 1939. Of workers who normally seek a livelihood by means of jobs of short duration, there were on the registers in Great Britain 49,670 unemployed persons. This was 2,008 more than at December 11, 1939, but 15,898 less than at January 16, 1939. The total of 1,518,896 persons on the registers at January 15 included 1,346,015 applicants for benefit or allowances, and 172,881 non-claimants.

In the industries for which statistics are regularly compiled by the Ministry of Labour and National Service, the changes in rates of wages reported to have come into operation in January are estimated to have resulted in an increase of about 287,000*l.* in the weekly full-time wages of over 2,000,000 workpeople. The principal groups of workpeople affected included coal miners, whose wages were raised by varying amounts in different districts; workpeople employed in the manufacturing section of the cotton industry, who received an increase of 7½ per cent.; railway traffic workers, whose wages were increased by 4*s.* a week; and workpeople in the textile bleaching, dyeing and finishing industry. Other groups of workers whose wages were increased included hosiery operators, workers employed in the retail bespoke tailoring trade, flour millers, vehicle builders, heavy-chemical workers, and gas workers.

The number of trade disputes involving stoppages of work reported to the Department as beginning in January was 73. In addition, three disputes which began before January were still in progress at the beginning of that month. The approximate number of workpeople involved in these 76 disputes, including workpeople thrown out of work at the establishments where the disputes occurred, was 57,000, and the aggregate duration of the disputes in January was about 108,000 working days.

At February 1, the average level of retail prices of the commodities taken into account in the statistics compiled by the Ministry of Labour and National Service (including food, rent, clothing, fuel and light, and miscellaneous items) was approximately 77 per cent. above the level for July, 1914, as compared with 74 per cent. at January 1. For food alone, the corresponding increase at February 1 was 61 per cent., as compared with 57 per cent. at January 1. The rise in the index figure for food was due mainly to increases in the prices of meat, fish, potatoes, cheese and eggs. Except in the case of meat, the severe weather was an influencing factor. Among items other than food, the principal changes were increases in the prices of clothing.

The area previously known as the South-Eastern Division of the Ministry of Labour and National Service has been incorporated in the area of the Southern Division with effect from January 1. The extended Division will be known as the Southern Division, and will cover the following areas:—Kent and Surrey (less the portions in the London Division), Sussex, Oxfordshire, Buckinghamshire, Berkshire, Hampshire, the Isle of Wight, and, in Dorsetshire, the municipal borough of Poole, the urban district of Wimborne Minster and the rural district of Wimborne and Cranbourne.

The Arbitration Court of the Commonwealth has decided that the 44-hour week must be accepted as the standard for Australian industry except where special circumstances demand otherwise. According to *Industrial and Labour Information*, although the 44-hour week has been the statutory standard in New South Wales and Queensland for a number of years, and has been granted in practice by the Commonwealth Court to the majority of the industries under its jurisdiction, this is the first time that the 44-hour week has been officially accepted as the standard throughout the Commonwealth instead of the 48-hour week.

An Order issued in Germany applies, to domestic service, the restrictions on change of employment made by the Order of September 1, 1939. The employment exchanges, in examining applications for permission to engage a domestic worker, must take into account both the general condition of the labour market and the requirements of households with children, especially in the case of large families, as well as certain social conditions. The permit must be granted in certain cases, among which may be mentioned the following:—When the health of the mistress of the household does not allow her to carry out domestic work herself, when she is over 50 years of age, when she is carrying on or training herself for an occupational activity useful to the nation, or when the household includes persons requiring special attention, or when the position of the head of the family in public life imposes on him duties which make the domestic work especially heavy. In all such cases the issue of a permit to engage a domestic worker is subject to the condition that no member of the family is able to do the work. Further, permission to leave their employment must be refused to any domestic worker employed by a household falling under one of the conditions mentioned above when the state of the employment market makes it impossible to replace her.

Under measures taken by the Government of New Zealand for the regulation of labour matters in war time, it is prescribed that during the continuance of the regulations no person shall (*a*) be a party to a strike or lock-out or (*b*) encourage or procure a strike or lock-out or the continuance of a strike or lock-out, or (*c*) incite any person or any class of persons or persons in general to be or to continue to be a party or parties to a strike or lock-out. The term "strike" includes: (*a*) The act of any number of workers who are or have been in the employment, whether of the same employer or of different employers: (i) in discontinuing that employment, whether wholly or partially; or (ii) in breaking their contracts of service; or (iii) in refusing or failing after any such discontinuance to resume or return to their employment; or (iv) in refusing or failing to accept engagement for any work in which they are usually employed. (*b*) Any reduction in the normal output of workers in their employment. (*c*) Any other transaction in the nature of a strike or combination, agreement, common understanding, or concerted action on the part of any workers, being (in any of the aforesaid cases marked (*a*), (*b*) and (*c*) of this definition) intended or having a tendency to interfere with the manufacture, production, output, supply, delivery or carriage of goods or articles or carriage of persons in or in connection with any industry or undertaking or otherwise to interfere with the effective conduct of any industry or undertaking.

The term "lock-out" includes: (*a*) The act of an employer (i) in closing his place of business, or suspending or discontinuing his business in any branch of it; or (ii) in discontinuing the employment of any workers, whether wholly or partially; or (iii) in breaking his contracts of service; or (iv) in refusing or failing to engage workers for any work for which he usually employs workers. (*b*) Any other transaction in the nature of a lock-out. (*c*) Any transaction in the nature of a combination, agreement, common understanding, or concerted action on the part of any employers relating to or connected with the employment of workers, being intended, etc. (the qualification is in the same terms as the definition of a strike above).

Provision is made for the appointment of an Emergency Disputes Committee, consisting of not more than seven persons (three representatives of employers, three representatives of workers and a chairman). If a dispute arises in an industry which is covered by an award or agreement providing for the setting up of a disputes committee, the dispute may be referred to that committee; disputes in other industries may be referred to the Emergency Disputes Committee. In all cases the decision given is to be final and binding on all persons directly affected by the dispute. The penalty for breach of the regulations is imprisonment for twelve months or a fine of 100*l.*, or both. The Minister of Labour is empowered to remove restrictions on overtime and has exercised this power in respect of defence and emergency works.

An Order in Council issued by the Canadian Government has made the provisions of the Federal Industrial Disputes Investigation Act specifically applicable for the adjustment of any dispute between employers and employees engaged in the construction, execution, production, repair, manufacture, transportation, storage or delivery of supplies and munitions of war, and in respect also of the construction, remodelling, repair or demolition of defence projects intended for the use of His Majesty's naval, military or air forces or for the use of the forces of any of His Majesty's allies in the present war.

The Act, which has been in operation for over 30 years, provides for the conciliation and arbitration of disputes in the mining industry, railway undertakings and public utilities. It declares illegal any strike or lock-out carried out before investigation of the dispute has been made by a board. The board is appointed by the Federal Minister of Labour, and is composed of three members, one appointed on the recommendation of the workers, one on the recommendation of their employers, and a chairman appointed on the recommendation of the first two members. In the course of time, eight of the nine Provinces of Canada have passed enabling Acts making the Federal law applicable to disputes which would normally come within provincial jurisdiction.

A communication received by the International Labour Office at Geneva states that more than 100 companies were represented at the fourth meeting of the Air Hygiene Foundation, which took place at Pittsburgh on November 14 and 15. The United States Public Health Service, the United States Department of Labour, certain labour organisations, and some State Departments, universities, institutions and individuals, had been invited to send representatives. Many aspects of industrial health were examined and discussed, including the employer's interest in costs, occupational-disease laws, industrial and public relations, the technical aspects of engineering precautions, absenteeism and recent medical progress made through Foundation researches. Mr. Robert J. Watt, member of the Governing Body of the International Labour Office, submitted an address on "Labour's Viewpoint on Occupational-Disease Prevention."

At a recent meeting in Belgrade of the Yugo-Slav Workers' Federation, a resolution was adopted urging the revision of the Legislative Decree fixing minimum wages and the conclusion of collective agreements and conciliation and arbitration. The revision should be such as to increase the minimum wage rate from 2 dinars to 4 dinars an hour. Together with this increase in the minimum wage, the committee also urged a general increase in wages in all public institutions of a local and autonomous nature, and in all State undertakings. It further demanded that representatives of manual workers' and salaried employees' organisations should be given a share in the management of State undertakings, of undertakings granted privileges by the State, and of important undertakings operated by municipalities; that regulations should be drawn up for workers' co-operative societies; and that the present regulations on unemployment assistance should be amended.

THE DEVELOPMENT OF IRRIGATION.

FIG. 1. INDIAN DOON WITH MOVING COUNTERPOISE.

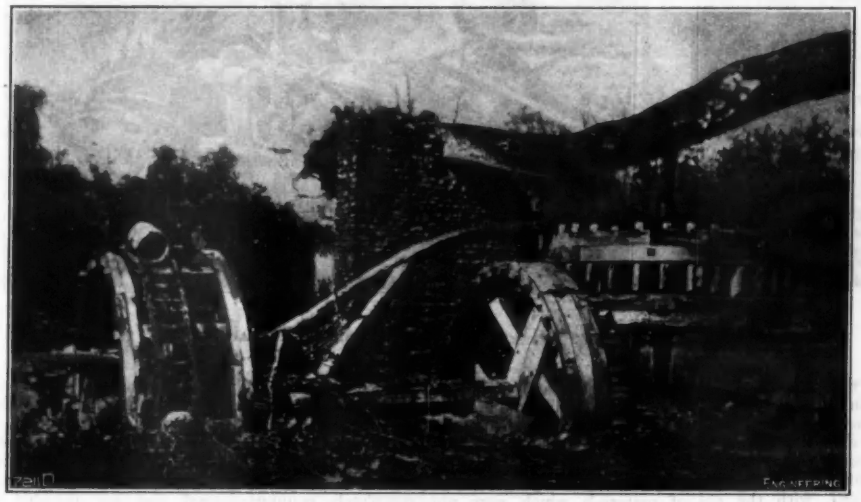


FIG. 2. PERSIAN WHEEL WITH PERIPHERAL BUCKETS.

IRRIGATION THROUGH THE AGES.*

By E. BRUCE BALL.

IN selecting the title for my address, "The Influence of the Mechanical Mind on the Development of Irrigation Through the Ages," my object is to illustrate the ingenuity of mechanical engineers and the importance of their influence on the development of the human race. Mechanical engineers may be defined as those whose mental powers are trained to solve, by mechanical means, problems of which the conditions and the results to be achieved are given. The mechanical mind was strongly developed from the dawn of civilisation when the early tribes and their flocks increased in numbers to an extent which made imperative migration from their original pastures to where natural water was readily available. Tracts of land were available which would become highly fertile if watered, but which lacked the accustomed natural supply, and on these the new inhabitants had to devise means to raise water from rivers or shallow wells. This was at first achieved by the use of pots or other carrying vessels. Probably the "basket scoop" was the earliest method devised to meet this increased need for water and to save time and labour in raising it, and thus it marked the dawn of the mechanical mind, which evolved an apparatus to accomplish this end. This method became, and still is, extensively used throughout the East.

Very soon the need was felt for improved methods of utilising to better advantage the labour available, and in the early history of man a great variety of mechanical devices was developed. These were constructed in the only available material, namely, growing timber. Many of these have survived, with little or no change through the ages, to the present time. One form embodies the principle of the pendulum, and is known as the "scoop" or "mantie." It is still in use in South India, and the water load is taken by a method of suspension. Another, employing the principle of the balance, is the "doon," still to be seen in Bengal for lifts of about 2 ft. to 3 ft., and is usually made from half the stem of a palm tree hollowed out. The weight of a man is used to depress one end into the water of the river or other source and a counterweight raises it sufficiently to discharge into the irrigation canals behind the river bank. When the demand arose for increased capacities, the mechanical mind devised moving counterpoise along the balance beam, Fig. 1.*

Probably the most universally used device is the Egyptian "shadouf," Fig. 3, page 236, working on the same principle as the "doon," but designed for higher lifts of 4 ft. to 10 ft. This is a crude but simple and efficient mechanical contrivance, and has survived from ancient times. The counterpoise is of clay bound to the oscillating beam, and clay piers support the cross beam. It is of interest to note that the remains of one were found in the tomb of Thebes, where they are also represented in sculpture dating from B.C. 1550 to B.C. 1532. Although their use is widely spread throughout the East, they have the same elementary construction as shown in the example. Thus, the Indian "Picottah" is almost identical and is sometimes used in series for raising water over high river banks. In some cases a man walking on the lever forms a moving counterpoise. By means of this the effort required to overcome the counterpoise when returning the basket to the water, as well as the upward lift, is almost eliminated and it is an early example of an energy-saving device.

A new problem arose with the need to draw water from greater depths and this was solved by the evolution of the pulley, a truly epoch-making event. It also made possible the employment of animal power in place of man, by converting the vertical lift into a horizontal pull, a momentous step in mechanical evolution. The device, consisting of a frame not unlike colliery head gear, with a bucket replacing the cage and an animal replacing the winding engine, is known as the "Mote," and has come down the ages with little change except some mechanical refinement in the way of a leather tubular extension of the vessel, to the lower end of which a form of valve is fixed. The valve is operated by a cord when the bag is at the top of its lift, allowing water to escape into the irrigation channel. It is observable from the angle of the frame that the method of dealing with resultant forces was perfectly understood. The principle of assisting tractive effort by gravity was known and adopted in those far-off days, a sloping path being employed, down which the animals walked when receding from the well, thus applying their own weight in raising the water. The development of the mechanical mind is again in evidence in the application of a very sound device for maintaining the outlet of the discharge trunk above the water level in the vessel during its upward travel, and automatically discharging the contents when fully raised by means of a lower rope, attached to and travelling with the hoisting rope. At a very early period wells became deeper, frequently reaching a depth of 200 ft. to 300 ft., and this provided a further incentive for the exercise of mechanical ingenuity, ox-driven winding gear being used and reversal being effected by the simple method of causing the oxen to change their relative positions and face the other way. A pivoted connection between the centre of the yoke and the driving arm readily permits of their turning round to apply this effort in the reverse direction of travel.

When the demand arose for improved appliances to raise greater volumes of water, and at the same time to employ the available labour for the cultivation of larger areas, the ancient mechanicians evolved the constant-delivery rotating machine in various forms, and at first used animals exclusively as the motive power. Much ingenuity was exercised in their construction, and of these machines the Persian Wheel is the most common and universally used. Fig. 2, annexed, shows a fairly heavy and advanced construction of the gearwheels. It may be noted that in the Sudan, in the province of Dongola alone, there were at work 3,892 of these machines in 1904, each irrigating on the average 15 acres of land and supporting 33 persons. The lantern design of wheel staked on to the shaft is common, and, it should be noted, this type of gearing was extensively adopted in the water-wheel driven mills in this country. Often during the height of the irrigation season these wheels are worked continuously, and in the stillness of the night, both in Upper Egypt and in the Sudan, I have heard the very peculiar and insistent chorus of creaking and groaning arising from their unlubricated wooden shafts and bearings. Another type, the "Noria," shows a higher stage of mechanical design as compared with the "Sakia" or Persian Wheel, since the separate pots are replaced by a continuous box-section rim to the wheel, which rim is divided into sections, each section having an inlet and outlet opening. This type is inferior in hydraulic efficiency. The "Noria" presumably antedates Egypt's Fifth Dynasty, 2560 B.C., when she reached the zenith of her civilisation, and her art, in particular, attained a perfection never again approached.

The mechanical mind next applied itself to use the energy in flowing water to replace animal power. Many examples have survived, such as the self-propelled Persian Wheel, still to be seen in Iraq on the Tigris and the Euphrates, with the pots suspended between two rim members of the wheel. The paddles themselves are generally formed of matting. Another example, showing the mechanical skill of the Chinese, is a gigantic wheel on the Yellow River. Suitable lengths of bamboo stems or containers set at an angle of about 50 deg. are substituted for the usual earthenware pots, and are lashed to the periphery of the wheel. The fertile mechanical ingenuity of the Chinese produced the link chain pump, according to some authorities, over 3,000 years ago, and these have continued in use with little change to the present day. Their problem was to transfer large volumes of water from canals or from field to field under relatively low heads and over sloping banks.

The Persian Wheel or Chain of Pots was undoubtedly known to them, but the difficulty attending their use in an inclined position, and the need to protect the pots when descending rough banks, would lead to the idea of substituting an open trough with pieces of wood fitting the full width and pushing the water before them with the motion of a wooden link chain, thus forming an endless conveyor. A self-contained portable type affords an example of its constructive application. It is operated by two persons, and the

* Presidential Address delivered before the Institution of Mechanical Engineers, on Friday, February 16, 1940. Abridged.

* The address was illustrated by 37 figures, of which 14 have been reproduced. The figure numbers do not agree with those used by the author.—ED. E.

THE DEVELOPMENT OF IRRIGATION.

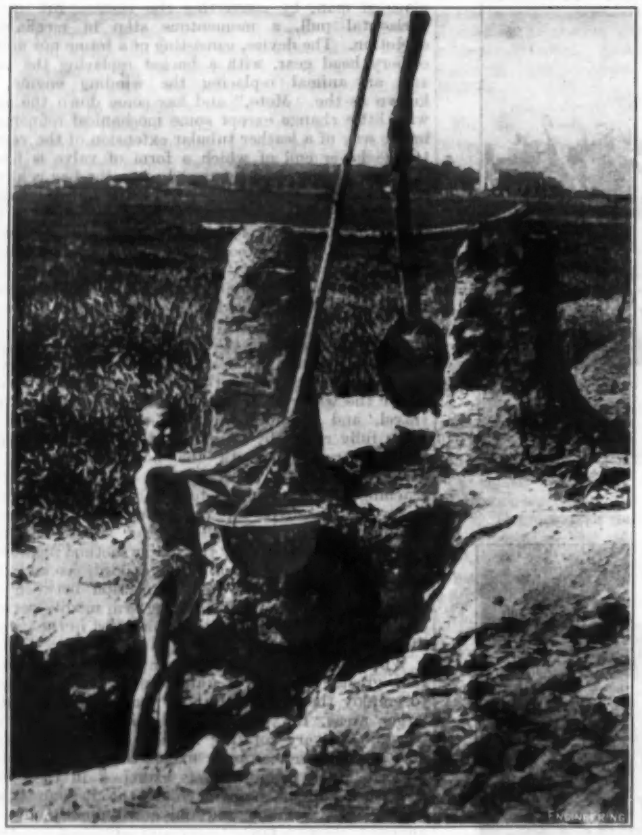


Fig. 3. Egyptian Shadouf.

Fig. 4. Chinese Link-Chain Pump.

cranks are set at 90 deg. Another self-contained unit for operation by one man is also worked by cranks fixed at right-angles, with a pair of sticks acting as connecting rods. For higher lifts or large capacities the tread mill type, Fig. 4, on this page, is universal and is constructed for operation by two, three, or four persons. The end thrust of the shaft is taken by the vertical poles, and the height of the lift is adjusted by the position of the pegs supporting the end bearings.

During my travels in China, extending to nearly five years, I saw numbers of these machines at work, and was much impressed by their effective design and construction; practically all were made entirely of wood and all members were connected by mortised joints or pegs. The wooden chain and pins also afforded an example of interchangeable manufacture, as practised from very early times. These machines are exceedingly numerous, nearly every peasant possessing one. When a breach occurs in the canal or flood-protecting banks, hundreds of cultivators are called with their machines after the repairs have been made, and by their means the water is drained from large flooded areas in a short time.

During many centuries the design and construction of mechanical apparatus remained practically stationary, due to the rarity and costliness of materials other than wood and to the difficulty of working them. With the development of the science of metallurgy, the mechanical engineer was provided with the means which made possible the extraordinary scope and magnitude of present-day irrigation works. This stagnation of mechanical development was not by any means due to want of incentive, for the need of effective control apparatus must have been very acute even in the early days, when the cultivation of large tracts of land commanded by the head waters of rivers was beginning to be undertaken. The method then available was the construction of temporary dams or weirs of timber or brushwood and earth, to divert the water into upstream take-off canals for distribution over the land. Each year these obstructions had to be removed, or were carried away by the flood waters, and they were reconstructed for the following irrigation season.

Solid permanent dams were not permissible, because of the obstruction they offered to the passing of floods with their burden of trees, silt and sand. If arrested, they would rapidly accumulate, raising the bed of the river upstream of the dam and causing loss of control in training the river, with permanent and disastrous results. For such conditions, the impounding dam must be readily removable during flood periods, and be available for replacement as soon as the floods have passed. The construction of such a dam involved problems which could only be solved by mechanical means, with the aid of materials which were not available to the ancients. An example of a dam of this type is shown in Fig. 5, Plate XI. It consists of a series of automatic collapsing shutters, pivoted on the crest of a low weir, near bed level.

The tripping of these shutters in times of flood is started by the release of the shutter nearest one abutment. By an ingenious mechanical construction the support of each neighbouring shutter is tripped in succession, until the whole series falls like a pack of cards, flat on the river bed. This practically restores the river bed to its original condition, and allows all floating debris and accumulated silt to be swept over the shutters without hindrance. In the first installations the shutters were reset by manual labour, Fig. 6, Plate XI, sometimes assisted by a travelling block suspended from an overhead ropeway, but more recently a travelling resetting machine, Fig. 7, Plate XI, has been employed, with a winch-operated fishing tackle to raise and lock each shutter in its vertical position. This illustration also shows the shutters falling immediately after the first one has been tripped.

The successful construction of masonry impounding dams on large rivers commenced about 1843, and was made possible by the aid of the mechanical engineer in designing and constructing submerged iron sluice gates mounted on rollers with fixed axles, usually regulated by means of travelling gantries with powerful winch gear. The limitations of water load and impounded head for this type of sluice necessitate the dam being constructed with a great number of narrow openings, and a corresponding number of piers which cause an appreciable afflux when flood water is being passed.

The high cost and unsuitability of this type of structure for great rivers with sandy beds prevented vast areas of suitable land from being brought under cultivation, and it was not until 1880 that the mechanical mind made possible the construction of barrages with wide and deep gates through the application of the anti-friction free-roller principle, to replace the fixed-axle type. By means of this device gates 60 ft. in width and from 12 ft. to 25 ft. in depth have become the present-day standard, and examples are to be seen in the Punjab and elsewhere. For special conditions many gates have been made greatly exceeding these dimensions. These barrage gates are all completely counterbalanced, and are provided with independent operating gear. So efficient are they that they can be easily raised by the effort of two men with water loads of 500 tons on the gates.

A typical example of a modern sluice-gate barrage is to be seen in the aerial view of the Panjnad Barrage in the Punjab, Fig. 8, Plate XI. This comprises forty-seven free-roller sluice gates, each of 60 ft. span, and is the last of four barrages on the Sutlej River. It is situated immediately below the junction of the tributary rivers, Jhelum, Chenab, Ravi, and Beas. The canals taken off from these rivers irrigate 11,000,000 acres of what was previously barren land. Fig. 9, Plate XI, shows a similar barrage on the Sarda River in the United Provinces, near the foothills of the Himalayas, situated in the heavy shingle zone. Several of these thirty-four 50-ft. span gates are fitted with automatic lifting gear to release sudden floods, and the remainder are operated by hand. Fig. 10, Plate XI, shows the general construction of the barrage. The Sarda Canals and branches supplied by these head works extend to 6,000 miles. The cost of their construction was 7,000,000*l.* and the work occupied eight years for completion; the area irrigated is 1½ million acres.

Electrical operation of sluice gates is adopted where large sizes and numbers are involved. Where each gate is fitted with its own independent motor the operating crew is reduced to one or two men. In cases where two or three portable motors or small oil-engine units mounted on trolleys are adopted, a crew of three men for each is usual. Fig. 11, Plate XI, shows the arrangement of the independent motor-operated type. The gates are 60 ft. span by 20 ft. deep; each weighs 52 tons, and the water load on the gates is 385 tons. To reduce the height of the overhead superstructure, the counterweight is frequently suspended in the bight of the wire rope. By this means the counterweight travel is half the gate lift, and in consequence is double the weight, to preserve balance.

Where suitable foundations are to be found, masonry dams can now be built far greater in height than their original prototypes, due solely to the mechanical

THE DEVELOPMENT OF IRRIGATION.

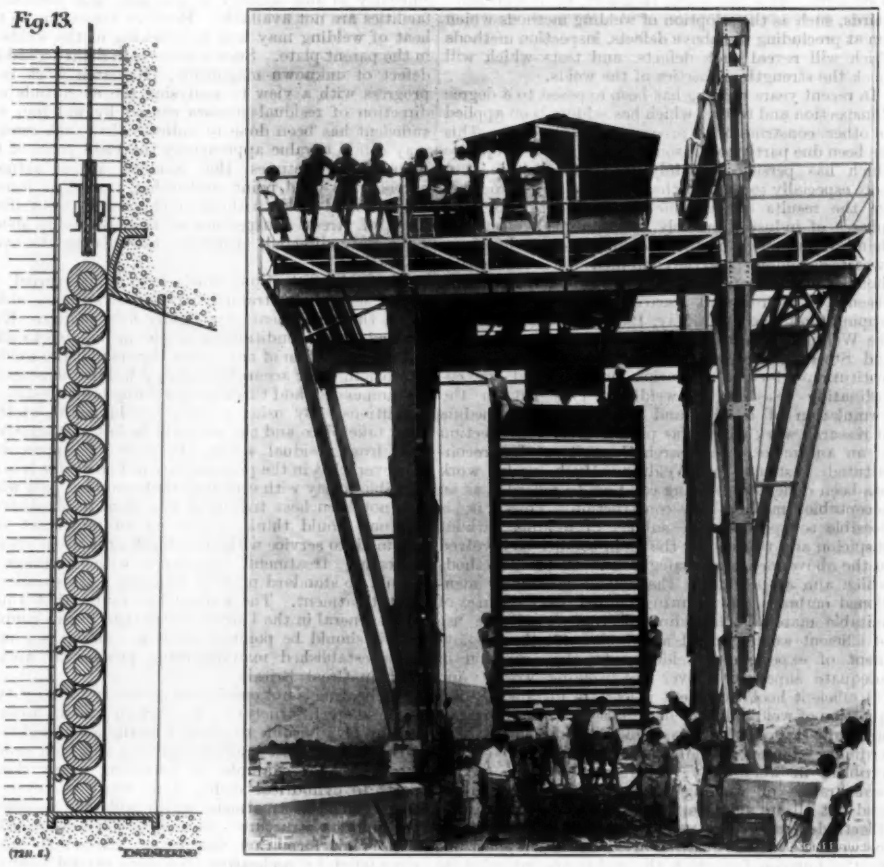


FIG. 14. EMERGENCY CLOSING GATE.

application of free rollers to sluice gates. The introduction of this design immediately opened the way to the creation of vast reservoirs of great depth, by making possible the use of regulating sluices under high heads. It should be realised that the creation of the Aswan Dam as it is to-day, impounding the waters of the Nile to a depth of 120 ft. and extending upstream to a distance of 200 miles, was only possible through the ingenuity of the mechanical engineer, whose control machinery enables the full flood flow to pass through the sluice culverts formed in the heart of the dam. Another example, Fig. 12, Plate XI, shows the recently-completed Gebel Aulia Dam on the White Nile, which, when fully impounded, will store the flood waters for a distance of 190 miles upstream.

The problem of isolating these submerged sluice culverts, for examination and maintenance of the sluice gates and under-water parts without emptying the reservoir, was also solved by the mechanical engineer by an extension of the free roller principle to the design of a shutter gate or curtain, shown diagrammatically in Fig. 13, above. This gate is lowered down the face of the dam, and is capable of closing any of the culvert openings under full impounded head, with full sluice opening and free discharge. It consists of a number of main rollers spanning the culvert opening, held between side frames and rotating on axles. The spaces between the main rollers are occupied by smaller staunching rollers, which are kept in position by the hydraulic pressure, and are rotated in the opposite direction by the main rollers. The whole assembly forms a completely free rolling unit, and cuts through the high-velocity stream of water by virtue of its weight, which is much greater than the frictional resistance to movement arising from practically pure rolling alone. Fig. 14, on this page, shows an example of this type of emergency closing gate for closing culverts under 150 ft. head.

Irrigation plays an important part in the life of a nation by giving employment to its people and eliminating recurrent famines which formerly decimated the population. This is shown by the fact that in India alone the area irrigated represents 59,000,000 acres in average years, or approximately one-fifth of the total cultivable areas. About 50 per cent. is irrigated from canals, 25 per cent. from wells, and 25 per cent. from lakes, small streams, and other sources. The capital invested in Government canals is 115,000,000*l.*, which yields a net return of 5½ per cent. It may also be mentioned that in Madras Province 7,000,000 acres are irrigated by the waters of the Cauvery-Kistna and Godavari Rivers, whilst the Sukkur System in Sind now irrigates 5,300,000 acres of desert land with a total length of major canals and minor branches of 5,500 miles; this was constructed at a cost of 15,000,000*l.* Part of the potential water power available in these irrigation works has, in recent years, been developed, and to this the mechanical engineer has contributed his full share. Although much has already been done, there are vast resources still awaiting development.

These few examples, from only one branch of our profession, illustrate the important part played by the mechanical engineer in assisting nature to maintain the population of the world, and to raise universally its standard of living. What I have said may be regarded as one illustration of the dependence of human life on the creative work of the mechanical engineer. This dependence applies equally to the vital part played by science and industry, as represented by all engineering institutions, in our present-day civilisation and mode of life. The work of the mechanical engineer embraces transport by land, sea, and air, the production of food and clothing, all essential services such as the distribution of purified water, hygienic sanitation, the harnessing of electricity to our needs, and the provision of the amenities within our homes, as well as the highly mechanised equipment of our Navy, Army and Air Force, on which depends the safety of our country and Empire.

The importance of the work of the engineer entitles him to wider recognition and the opportunity to contribute a greater share in the councils of public affairs. In his status of citizen he has had the opportunity of higher education and is in a position to give critical thought and support to measures initiated for the public good. As a result of his education and experience, he is trained in the technique of honest thinking. He analyses current problems by reducing them to their simplest terms and discriminates between reliable and faulty data. He is trained to distinguish between the possible, the probable, and the actual. A basic contribution of the engineer to society is his respect for the truth and his training in reasoning correctly and cautiously from given premises. The engineer, in speaking to the public, tends to argue for the "best plan", to tell the "whole truth" as he sees it, partly because of his education, partly from habit, and partly because of his reputation for being logical, consistent and impartial.

It is encouraging to find that his experience is now being utilised to an increasing extent in an advisory capacity by the Government of to-day. The present emergency has afforded this opportunity and it is to be hoped that it may become a permanent feature in the administration of the country.

WELDING AS A SUBSTITUTE FOR CASTING.*

By S. F. DOREY, D.Sc.

THE object of this paper is to indicate the progress that has been made in the substitution of welded mild-steel parts for ferrous castings; for convenience these may be termed "weldings." For certain parts in engineering construction cast iron has for long been regarded as the most suitable material for both the strength and economic points of view. In recent years, however, the development of fusion-welding processes has led to the increased use of mild steel for parts where cast iron was formerly employed. A considerable reduction in scantlings can generally be adopted, and in consequence a proportionate saving in weight is obtained.

It is sometimes claimed on behalf of weldings that first cost is less than for castings, and while in certain instances this may be true, it should not be the primary reason for the adoption of welded parts. In castings required in large numbers, a small number of patterns can be used over and over again, and in consequence first cost will probably be less than for welded parts. Against this, it may be claimed for welding of larger parts that there is a saving of time on patterns and possibly also on rejected castings; there are also reduced machining costs.

In the author's view, it is only necessary to consider the substitution of weldings for castings when it is important to restrict weight, or when it is considered that a better or more suitable article can be made by the employment of welding. To ensure a sound casting it is necessary to avoid as far as possible large variations in thickness, whereas in a welding there is no limit to the extent of the variations, and material can be distributed to afford the best resistance to service stresses. Another advantage in welding is the ease with which modifications in design can be effected during actual manufacture.

The main advantages of mild steel over cast iron are its considerably higher elastic modulus and its better resistance to the effects of temperature. For the same strain the ratio of the permissible stress in mild steel as compared with cast iron is approximately 2 : 1. From the practical design point of view, however, it would be more useful to note that, for the same conditions of loading, the modulus of the section in mild steel need only be about one-half of that in cast iron.

Reduction in weight may not, however, follow in the same ratio as the elastic modulus, for the reason that in substituting welded mild steel for cast iron the question of rigidity may arise. In a welded structure it is necessary to ensure adequate rigidity by adopting a suitable and efficient system of webbing and bracing. The required stiffening sets a limit to the weight reduction that might otherwise be possible. Despite the necessity of providing for adequate rigidity, savings in weight of between 20 per cent. and 40 per cent. over cast iron are possible. As an example of a part in which rigidity and resistance to crushing forces are important, reference might be made to a welded mild-steel base for a 750-ton keel-bending press, installed early in 1939 at Chester, Pa. The weight of this base was 39 tons, as compared with 48 tons, the weight of its cast-iron predecessor, which had broken. This welded-steel base was 27 ft. by 9 ft. by 4 ft. 7 in. in depth, and while it was about 20 per cent. lighter than the previous cast-iron bed, it was estimated to be considerably more rigid by virtue of a heavy system of webbing.

It cannot yet be said that in this country there has been an extensive change from cast iron to welded mild steel. The trend in that direction, however, is apparent, and it is better, from the point of view of reliability and safety, that the transition should be slow and gradual, allowing time for the accumulation of experience. In marine installations, parts now commonly made in welded mild steel are main and auxiliary engine bedplates, pipes and pipe flanges, oil and water heater bodies, condensers, evaporators, steam traps, superheater headers, eduction pipes, turbine cylinders and gearcases, armature hubs and

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, in Glasgow, on Tuesday, February 20, 1940. Abridged.

stator frames, and bedplates for such items as windlasses, capstans and winches. In addition, sundry valves, brackets and pedestals, formerly made of cast iron, are now frequently manufactured in the form of weldings. In the construction of electrical generating plant, welding is now common practice in the building of stator frames, armature hubs and spiders, and bedplates. Other electrical apparatus, such as transformer and switchgear tanks, and the vacuum type of container, are specially suitable for welding from the point of view of oil-tightness and resistance to internal pressure. One of the main advantages of welding over casting is that the designer is not tied to a range of standard castings. This may be of special importance in such items as pedestals, yokes, switchgear, and hubs and bedplates for generating plant.

It is often said that, when replacing a casting by a welding, the designer should forget all about the shape of the casting and design purely from considerations of welding technique. However excellent this idea may be in theory, the fact is that in designing a welding it is usual to have very much in mind the shape of the cast prototype. This surely is the rational procedure to adopt, for it takes full advantage of past experience which has proved a particular "shape" to be the most suitable for the function it is intended to fulfil. There are, however, certain general principles which should be used, as far as possible, as a guide in the design of weldings, namely, to make full use of standard rolled and pressed shapes and sections; to avoid abrupt discontinuities in design and keep welds clear of positions where stress concentrations may occur in service, or where stresses may be of complex character; to restrict the size of welds to a minimum consistent with strength and efficient attachment of the parts joined; to avoid placing two or more heavy welds so close together that their shrinkage when cooling will impose severe tensions in the plate material between them; and to keep in mind the question of accessibility for welding and for subsequent inspection. Further, important welds should be made in the horizontal downhand position.

To summarise the most important examples of welding replacing casting, the following appear to be representative:—In marine-engineering plant—bedplates and columns, condensers and evaporators, and heater shells; in electrical-engineering plant—bedplates, stator frames and armature hubs and spiders, low-pressure turbine cylinders, transformer tanks, and switchgear; general—gearcases and gearwheel centres, bearing brackets of special design, rolling-mill parts, and heavy machine-tool frames.

Lest it be inferred that the author visualises the time when cast iron will be a thing of the past, it must be stated that for quantity production of low-stressed parts of standard design the iron foundry will always offer the most economic and satisfactory results. It is thought, however, that cast iron will be used in a decreasing degree for the manufacture of those important parts of engineering plant mentioned above.

This is a steel age, and steel, either cast, forged or welded, in the plain carbon or alloyed condition, is the primary material in engineering construction to-day. Accordingly, it is necessary to differentiate between iron castings and steel castings when discussing the relative merits of casting and welding. A steel casting can exhibit the highest qualities in strength, toughness and resistance to corrosion and high temperatures. With the addition of alloying elements, a range of properties can be obtained designed to meet the variety of service conditions of stress and temperature to be found in modern engineering plant. The substitution of weldings for iron castings may, therefore, in certain circumstances, be regarded as a desirable proposition, whether from the point of view of improvement in the quality or suitability of the product, or simply on account of the economy in production costs. But where steel castings are concerned, welding has very definite limitations, mainly because the weldability of certain alloy steels is still in the experimental stage, and because for certain parts of special design intended for high internal pressure, accessibility may be too difficult to ensure sound welding. Highly stressed welds should always be made from both sides of the joint.

It has been found that, for certain parts of machinery installations, a useful combination of welding and steel castings can be employed. Thus in steam generators, such as the Velox and Loeffler boilers, tubes and elements are welded to cast-steel headers. In certain turbine cylinders and gearcases, it has been found desirable to incorporate cast-steel components, such as bearing housings, which are welded to the mild-steel structure. The main bearings on welded bedplates for reciprocating engines are sometimes housed in cast-steel pedestals. Present tendencies indicate an increasing use of carbon and alloy steel castings and forgings in conjunction with welded components, and a more extensive substitution of weldings for iron castings. The main defects in fusion welding which it is necessary to guard against are bad penetration, inclusions (gas or slag), undercutting at the sides, cracks, and distortion. Although all these defects might be successfully avoided, a weld may be produced which is still deficient in strength. It is necessary, therefore, to provide safeguards, such as the adoption of welding methods which aim at precluding the above defects, inspection methods which will reveal such defects, and tests which will check the strength properties of the welds.

In recent years welding has been exposed to a degree of inspection and testing which has seldom been applied to other constructional processes in the past. This has been due partly to the somewhat stubborn prejudice which has persisted, mainly in Great Britain, but more especially to the fact that fusion welding processes are the results of scientific development in several spheres of industry, namely, metallurgical, electrical, chemical and mechanical. Welding, to-day, therefore, owes its development to the combined efforts of scientific thought in a variety of important industries. In the absence of co-ordinated research, a good deal of overlapping took place. In May, 1935, the Symposium on the Welding of Iron and Steel, organised by the Iron and Steel Institute with the collaboration of other institutions, focused attention on the need for co-ordinating research in welding. This led to the formulation of a wide and comprehensive schedule of research work which was placed under the direction of an authoritative Research Committee of a reconstituted Institute of Welding. Much useful work has been done, and welding can now be regarded as an acceptable method of construction. Thus, it is possible to approach the subject of welding without suspicion and to consider the main conditions involved in the above-mentioned safeguards. Welding methods which aim at precluding the defects previously mentioned embrace the following factors: (1) the use of suitable materials, including electrodes; (2) the use of efficient welding plant and tools; (3) the employment of experienced welders; (4) the provision of adequate supervision over the welding work; and (5) efficient heat treatment in certain instances. The question of weldability of materials becomes of increasing importance in the sphere of alloy steels. For ordinary commercial mild steel there is no serious problem in weldability. There is, however, a very wide range of welding electrodes available to-day and not all are suitable for the highest class of work. Electrode makers are usually careful to discriminate between the various qualities of their products according to the purpose for which the welds are intended, or to the specification which it is required to meet. Nevertheless, it is suggested that, for important welded work, a very careful selection of the electrode should be made.

The most sensitive test for grading electrodes, as well as for judging the standard of workmanship, is X-ray examination. It is, of course, essential to interpret X-ray photographs with intelligence, and with a full appreciation of the various factors in radiographic technique which affect the results obtained. For the selection of an electrode, the test plates should be prepared by one experienced welder, and the X-ray negative corresponding to the electrode selected should thereafter be regarded as the standard for assessing workmanship using that particular electrode.

The human element in welding, admittedly important, is no more important than the human element in many other spheres of engineering construction. Good welding requires a skilled workman, and the best work calls for experience and a high degree of competence. Slag inclusions and undercutting are typical defects that come under the welder's control. In oxy-acetylene welding the correct mixture of the gases in the burner is under the control of the welder, who should be able to detect slight changes in the welding flame which are likely to affect the quality of the weld metal. An experienced welder should have a practical knowledge of the effect of welding heat on the parts being welded. Accordingly, he should be able to arrange the sequence of his welding and the direction of deposition in such a way as to have the least detrimental effect either in distortion or cracking, or both. Such details as size of electrode, amperage, and speed of welding are also factors with which an experienced welder is intimately concerned.

These and other problems of technique are also the concern of the welding supervisor; the employment of experienced welders, together with efficient supervision, are of first importance in ensuring sound welds. All these details may be grouped under the heading of procedure control, which, in the author's view, is a more effective safeguard than any testing methods that may subsequently be employed.

The question of the need for heat treatment of welded parts is one which, in this country, is as much influenced by the facilities available as by the technical merits of the case. This is illogical, because the necessity for heat treatment has nothing to do with the facilities available. Unimportant machinery parts, or parts of simple design and intended for low working stresses, may safely be put into service in the "as welded" condition, but, in the author's view, heat treatment is of such value as a safeguard that it should be adopted wherever possible. It is of no credit to industrial efficiency in this country if adequate heat treatment facilities are not available. Residual stress due to the heat of welding may lead to cracking in the welds or in the parent plate. Such a stress is in reality a hidden defect of unknown magnitude. Research work is in progress with a view to analysing the magnitude and direction of residual stresses caused by welding, and sufficient has been done to indicate that such stresses may attain a value approaching the yield point of the material. Sometimes the residual stress actually exceeds the yield point, and either a crack is formed or the metal yields without cracking and thus relieves itself of stress. Inspection of finished welds should be mainly directed, therefore, towards the discovery of cracks.

To avoid distortion, much welding is carried out under severely restrained conditions, such as obtain when the components are rigidly held in jigs. Even under "free" conditions it is seldom possible to allow complete freedom of movement throughout the welding operation. For accurate work, jig welding is generally recommended, and this means welding under restrained conditions. By using a ductile weld metal, yielding may take place and the part will be left comparatively free from residual stress. It must be appreciated, however, that in the present state of knowledge it is not possible to say with certainty that a welded part which has not been heat treated is free from residual stress. No one would think of putting an important steel casting into service without subjecting it to an efficient annealing treatment. Similarly with weldings, it should be standard practice to apply a stress-relieving heat treatment. The author has found that this is more general in the United States than in this country, and it should be pointed out that welding is a much older established manufacturing process in America than in Great Britain.

Preheating is not considered necessary for large types of mild-steel structure. In certain cases, however, it may be advisable to preheat locally as an additional precaution against crack formations and high residual stress, as, for example, in attaching heavy flanged parts to cylindrical shells. Care must be taken not to prolong this treatment which will tend to coarsen the granular structure. In alloy steels, weld shrinkage and crack formation due to air hardening can be eliminated by preheating, but here careful control is necessary. Temperatures varying from 200 deg. to 600 deg. F. have been successfully employed.

It has been stated that the inspection of a finished weld should be mainly directed towards the discovery of cracks. Where reliance is placed on visual inspection for cracks, it is good practice to sand blast the part after heat treatment. One American firm applies heat treatment and sand blasting to the bedplates and columns of a well-known type of heavy oil engine. The firm's welding is of the highest class, yet they consider this practice an essential safeguard against failure. Neither heat treatment nor sand blasting are common practices in Great Britain for welded structures of this type. In special cases, such as gearcasings, valves and steam-pipe fittings, sand blasting is particularly desirable for removing the mill scale and cleaning the welds.

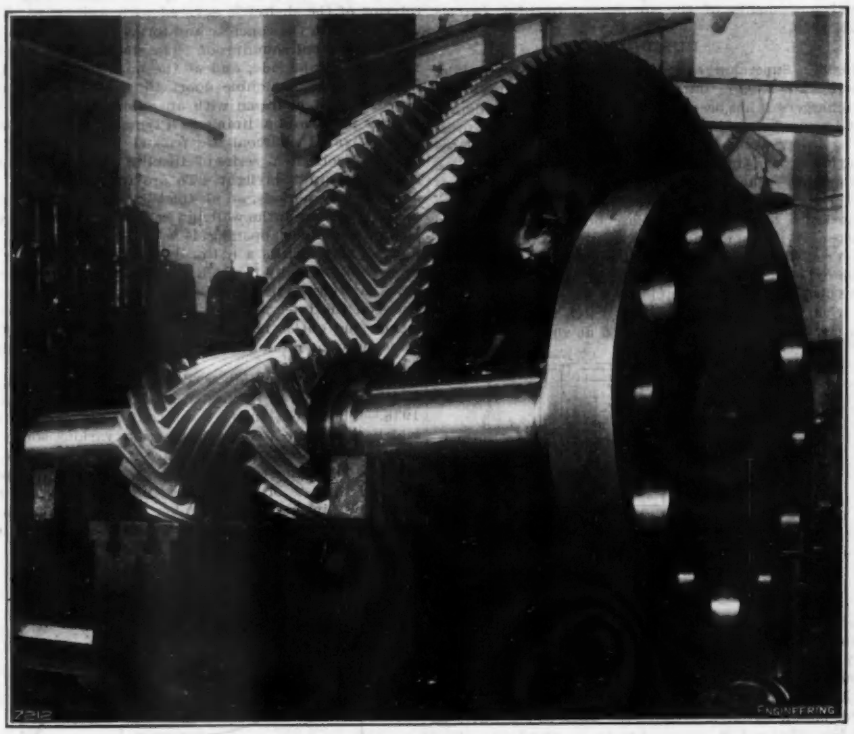
Crack detection has been placed on a scientific basis by the development of magnetic and X-ray methods. Magnetic methods include two main forms, one in which the article under test is magnetised and sprayed with a colloidal fluid of powdered iron, and the other which necessitates the use of instruments for measuring magnetic potential drop or flux leakage between two points. The former magnetic method is generally preferred, as it is both simple and direct. The iron particles form up along lines corresponding to the breaks in the magnetic flux lines caused by cracks and voids, and the presence of such defects is readily observed. The X-ray method is more expensive, but is invaluable where a high standard is desired.

Few castings are free from the defects commonly associated with welds. Shrinkage cracks, slag and gas inclusions and "draws" would often be found in a casting were it subjected to the searching examination more often imposed on welds. It is to the credit of those responsible for high-class welding that their work will stand up to inspection methods which would normally be considered too severe to apply to castings or forgings.

A final safeguard is the testing either of the weld itself or of representative samples. The main tests applicable to the welding are the hydraulic test in the case of a pressure vessel, and a proof-load test in the case of a structural part. It is not, however, always possible to apply such tests, and reliance must therefore be placed on the results of mechanical tests on samples, representative of the part concerned. This entails the preparation of separate test samples, which should be made under precisely the same welding conditions as the part they are intended to represent. It is sometimes

TRIPLE-HELICAL SPEED-REDUCING GEAR.

MESSRS. DAVID BROWN AND SONS (HUDD), LIMITED, HUDDERSFIELD.



possible to incorporate the test samples in the actual welding, much in the same way as a test piece is incorporated in a casting. The tests may include tensile, bend and impact tests, and, in special cases, fatigue and corrosion tests. Generally, the tensile, bend and impact tests will suffice, and the results obtained should not be inferior to those for the parent material. No system of testing samples can be regarded as a complete guarantee of the welding work, and for this reason the importance of efficient procedure control during construction should be emphasised.

Sufficient has been said to indicate the relative merits of welding and casting, and while the subject lends itself to speculation and imagination so far as the future trend is concerned, it is considered that the technical advantages of welded mild steel over cast iron are definitely established for structural components, but will always be qualified by consideration of the economic factors, which will in many cases favour the use of cast iron. Some of the special close-grained cast irons now available exhibit qualities, such as resistance to abrasion, which could not be obtained with mild steel, but even in this sphere it is necessary to bear in mind the methods for providing hard surfaces by applying special wear-resisting metals by gas welding. In conclusion, there appears to be no ground for suggesting any serious competition between welding and iron casting. Each process has its legitimate sphere of usefulness and scope, and if in some instances these overlap, then choice will be guided by the well-defined merits of either process for the particular application.

TRIPLE-HELICAL SPEED-REDUCING GEAR.

AN excellent example of modern gear cutting is presented in the accompanying illustration, which shows a triple-helical speed-reducing unit recently completed by Messrs. David Brown and Sons (Hudd), Limited, Huddersfield, for a winding installation in a South African gold mine. The centres are 7 ft. 6 in. apart, and the face width is 36 in. The gears transmit the drive from an electric motor of 2,395 h.p., but are designed to stand up to a peak load of more than double that amount, viz., 5,078 h.p. The motor runs at 160 r.p.m., and the winding drum at 26 r.p.m. The gear wheel is of cast steel and is made in halves in order to facilitate handling in transit and assembly on the site. The pinion is integral with its shaft and is machined from a forging of high-tensile steel. The shaft is 16 in. in diameter in the coupling, which is 4 ft. 8 in. in diameter and is secured by a pair of tangential folding keys. These can be made out on the face of the coupling, and, as the gear is reversible, they slope in opposite directions. The gear teeth were formed with profile-ground end mill cutters and it will be noticed that the apices are relieved, a finish which eliminates the trapping of the lubricating oil. The total weight of the unit is 25 tons.

ELECTRICITY SUPPLY IN IRELAND.

IN an address recently delivered before the Irish Centre of the Institution of Electrical Engineers, Dr. T. A. McLaughlin, of the Electricity Supply Board of Eire, gave some interesting information regarding the increase in the use of electricity in that country during the last decade. The electric plant of the River Shannon, he said, went into operation in October, 1929. At that time there were two major power plants—one in Dublin and one in Cork—and throughout the rest of the country there were small local plants supplying electricity mainly for lighting purposes in many of the towns. In the area surrounding the centre of the present city of Dublin, electricity supply mains were limited to the suburbs of Rathmines and Pembroke and the centre of Dun Laoghaire. Large towns, such as Waterford, Sligo, Tralee, Wexford, and Drogheda, with populations varying from 27,000 to 11,000, were without electricity supply. The plant installed at the Pigeon House station, Dublin, had a capacity of 21,000 kW, while that in Cork was of 7,700 kW. The peak loads were 17,250 kW and 4,300 kW, respectively. The total electricity sold in the country during the year ending October, 1929, was 48 million kWh, of which Dublin and its immediate suburbs were responsible for 31 millions and Cork for 9 millions. Over half the consumption in Dublin was for lighting and domestic purposes. The total number of consumers was 50,500, of whom 26,000 were in Dublin and 4,200 in Cork.

At present, Dr. McLaughlin said, the capacity of the plant at Pigeon House was 80,000 kW, and it would shortly be increased to 100,000 kW. The peak load at Dublin was now about 48,000 kW, and that at Cork was 9,500 kW. The total electricity sold for public supply purposes was 276 million kWh., of which 107 millions were sold in the Dublin area. Of this total, 35 millions were used for power, compared with 13 millions ten years ago. The sales in Cork had increased to 24 million kWh, and in the rest of the country the figure was 145 million kWh, compared with 8 million kWh a decade ago. Of these, some 65 million kWh were consumed for motive-power purposes. The total number of consumers was 160,000, of whom 74,000 were in the Dublin area and 11,000 in Cork. The number of families in Dublin using electricity had risen from 27 per cent. to 67 per cent., and in Cork from 20 per cent. to 49 per cent. In Limerick, the number of consumers had increased from 885 to 6,461, and in Galway from 897 to 2,431. Similarly, at Dundalk, the increase had been from 985 to 2,168, and at Clonmel from 177 to 671. All these areas were supplied by small local plants a decade ago. About 1,200,000 persons, out of a total population of 2,900,000, were now living in areas served by the mains.

In considering the general question of advance, the most striking criterion was the increase in the sales of electricity. Excluding Dublin and Cork, the increase was from 8 million kWh to 145 million kWh, and also excluding Limerick, Galway and Clonmel, it was from 5½ million kWh to 129 million kWh. Ten years ago, about 10 million kWh were used for domestic purposes. This had increased to 84 million kWh in 1939. Apart from domestic sales, the consumption of electricity for general heating, cooking and water-heating reached 27 million kWh in 1939, whereas in 1929 this was almost negligible. The consumption per consumer for domestic purposes had now reached a reasonably advanced figure. In the suburbs of Dublin it amounted to 1,200 kWh, while in the city area it was 650 kWh. The figure for Cork and Limerick was about 550 kWh, and was 750 kWh for the rest of the country. The sales of electricity for industrial power in the year prior to the Shannon plant coming into operation were 20 million kWh for the whole of the country, while a decade later the figure was 115 million kWh. Of the 20 million kWh, 13 millions were sold in the Dublin area and 5 millions in Cork. The corresponding figures, a decade later, were 35 million kWh in Dublin, 15 million kWh in Cork, and 65 million kWh in the rest of the country. The total of industrial motors connected to public electricity supply mains had increased from 25,000 h.p. to 108,000 h.p. in ten years.

The great increase in the consumption of electricity for power in the area outside the two large cities was of particular interest, as indicating the spread of industrial activity throughout the country following the erection of electricity supply mains. The growth in the small towns and villages, where electric motors were now largely used to do work which previously could only be done by hand, was particularly noteworthy.

CATALOGUES.

Machine Tools.—From Messrs. Broadway Engineering Company, Limited, Carlisle-road, Hendon, London, N.W.9, we have received a leaflet giving the names of foreign machine-tool makers for whom they act as agents in the British Isles.

Universal Ball Joints.—Messrs. The Mollart Engineering Company, Limited, Kingston By-pass, Surbiton, Surrey, have published a brochure dealing with their patent universal joint, designed for specially-wide angles and fitted with grease-retaining covers.

Linesmen's Equipment, etc.—We have received from Messrs. British Insulated Cables, Limited, Prescot, Lancashire, a miscellaneous list, including, among other items, tool kits for telephone and power linesmen, instrument erectors and jointers working on rubber-covered cables.

Lubricants.—Messrs. The Rawlplug Company, Limited, Rawlplug House, Cromwell-road, London, S.W.7, have added to their business the sale of a penetrating mineral compound oil with the trade name of "Slip." This oil is stated to have exceptional creeping properties which facilitate rust removal.

Heavy-Duty Oil Engines.—Messrs. Crossley-Premier Engines, Limited, Sandiacre, near Nottingham, have published a catalogue giving particulars of several large installations of their heavy-duty oil engines of the horizontal *vis-à-vis* type. They are built in sizes ranging from 300 to 3,000 b.h.p.

Machine Tools for Aircraft Manufacture.—Messrs. William Asquith, Limited, Halifax, have sent us a catalogue describing machine tools for aircraft production. The machines include a range of profile millers, special drilling and boring machines, as well as a number of standard tools.

Soap and Glycerine Plant, etc.—Messrs. The Power-Gas Corporation, Limited, Stockton-on-Tees, in collaboration with Messrs. Wurster and Sanger, Inc., Chicago, U.S.A., have issued a leaflet giving particulars of equipment for the soap, glycerine, oil and fat industries. This comprises evaporators, deodorisers, catalyst and separating plant, oil-hydrogenation and hardening installations.

Hydraulic Machinery.—A catalogue of interest to marine engineers is that published by Messrs. Hyland, Limited, Wakefield, Yorkshire, describing their hydraulic windlasses, capstans, winches and hand and power steering gear. The last-named gear provides for an instant change-over from power to hand operation, and enables a ship to be steered from either of two positions.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AGRICULTURAL APPLIANCES.

515,915. Cattle Clipper. The Wolseley Sheep Shearing Machine Company, Limited, of Birmingham, and H. J. Macnamara, of Birmingham. (7 *Figs.*) July 5, 1938.—The invention is a vacuum-driven clipping head for shearing sheep and cattle. The head contains a wedge-shaped upper chamber B, and a lower chamber C. Within the chamber B is a flap pivoted along its rear vertical edge, the lower pivot passing down through the dividing wall between the chambers. The flap consists of two cup leathers secured by two external plates to a pair of middle plates, which carry the pivots. To the bottom of the lower pivot is secured a short lever carrying, on its underside near the free end, a roller which engages a slot

Fig. 1.

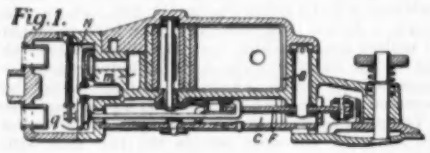
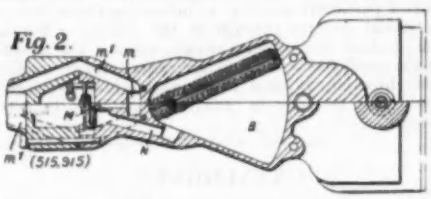


Fig. 2.



in a rocker F, which operates the cutter. At the rear end of the head is a valve chamber H, with a nozzle to which is connected a vacuum pipe. The chamber is open to the atmosphere. At the inner end of the chamber is an inset plate forming a valve face having a middle port M and two side ports N (see the lower half of Fig. 2). The middle port M is a suction port and connects by a passage m and two branches m^1 with the nozzle. The two side ports lead to the chamber B on opposite sides of the flap. The valve consists of a Bakelite cup set in the upper end of a valve rocker, which is branched at its lower end to engage a roller q mounted on the end of a spring rod, which passes into the chamber C. The roller q is held against one or other of the branches by a coil spring. The rod is bent up at its forward end and passed through a hole in the rocker F. The sides of the slot are bent down and the rod passes between them. When, therefore, the rocker is swung to one side by the lever and roller, it strikes the rod and causes the valve rocker and its valve to move over. This uncovers one of the ports N, exposing it to atmospheric pressure in the chamber H and connects the other port N with the suction port M. Thus the flap is reciprocated in the chamber B. (*Accepted December* 18, 1939.)

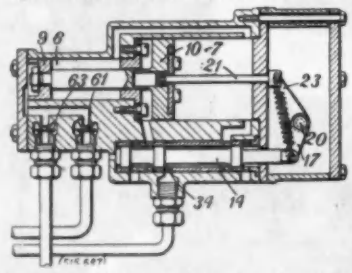
MOTOR ROAD VEHICLES.

516,062. Bogie Vehicle Suspension. G. E. Neville, of Mansfield. (4 *Figs.*) June 18, 1938.—The invention is a spring suspension for lorries and coaches which have two pairs of wheels at the front, all of which are steered, and aims at avoiding a change in the wheelbase when one set of springs is flexed. The springs A of the leading

axle are anchored at their front ends to brackets on the chassis and at their rear ends are connected to shackles D. Both ends of the springs E of the other axle are connected to the chassis by shackles F and G, and in order to keep the distance between the two axles within proper limits, the shackles D and F on each side of the chassis are connected together by a link H. For this purpose the shackles consist of two parallel triangular plates connected at their apices to the chassis. When the leading spring is flexed more than the other, the front axle moves back a short distance. This movement is transmitted by the link H to the rear spring and the rear axle is moved back. By adjusting the distances between the points where the shackles are connected to the chassis and the points where the link H is connected to them, it is possible to allow for the greater travel of the end of the spring than of the axle when the spring flexes and so control the position of the rear axle within required limits for all normal movements of the springs. (*Accepted December* 21, 1939.)

PUMPS.

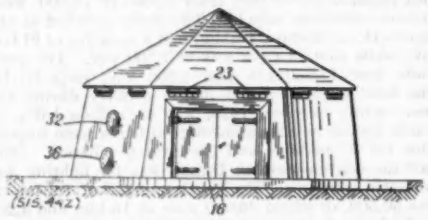
515,687. Supercharger Scavenge Pump. P. W. Bedale, of Derby. (3 *Figs.*) March 29, 1938.—With centrifugal superchargers, it has been found that, at small or moderate throttle openings, when the supercharger delivery pressure is below atmospheric pressure, petrol accumulates in the lower part of the volute chamber due to incomplete evaporation. The invention is a pump which removes this accumulation of petrol. Two coaxial cylinders 6 and 7 are separated by a plate bolted to the casing. A piston 10 in the cylinder 7 is secured to one end of a piston rod which carries at its other end a pump plunger 9 in the cylinder 6. A valve rod 14 brings alternate sides of the piston 10 into communication with the atmosphere and with the supercharger. The valve rod is operated from the piston by links 17 pivoted at 20 on the casing.



A rod 21, coaxial with the piston rod, has a collar which slides in a slot in the piston 10. At its other end the rod 21 is attached to links 23 also pivoted at 20. Tension springs connect the links 17 and 23. The ends of the slot in the piston 10 contact with the rod 21 at each end of the piston stroke and cause the links to snap over so that the valve rod 14 is moved from one end to the other of its chamber. Ports at the ends of the cylinder 7 communicate with the valve chamber at the ends of which are ports which communicate with the atmosphere, and a port 34 leading to the supercharger chamber. These ports are controlled by collars on the valve rod so that one side of the piston 10 is brought alternately into communication with the atmosphere and with the pressure in the supercharger. The piston is operated only when the delivery pressure of the supercharger is below atmospheric. The intake and discharge of petrol in the cylinder 6 is through valves 61, 63 operated by the pressures in the working space of the pump. The inner end of the cylinder 6 communicates, by a passage in the casing, with the outer end of the cylinder 7 so that the rear face of the pump plunger 9 is subjected to supercharger volute pressure during the intake stroke and to atmospheric pressure during the discharge stroke; thus the pressures on the two sides of the pump plunger are equalised. (*Accepted December* 12, 1939.)

MISCELLANEOUS.

515,442. Air-Raid Shelter. R. Atwill and Son, Limited, of Plymouth, The Holford Processes, Limited, of London, H. J. Holford, of Tavistock, and H. F. White, of Plymouth. (10 *Figs.*) June 1, 1938.—The shelter, which is gas-proof and bullet-proof, is built above ground level and can be used as a garage. It is hexagonal in plan, has a six-sided pyramidal roof, and is mounted upon a 12-in.



reinforced-concrete raft. The side walls are of reinforced concrete on steel frames and slope inwards from the raft so as to minimise the effect of an explosion in the neighbourhood. The reinforcement for the walls consists of a layer of upright ⅝-in. mild-steel rods, 6 in. apart, interwoven with horizontal stranded galvanised wire ropes of 1¼ in. circumference. The roof is of 15 in. concrete reinforced with two layers of 10-gauge expanded metal and carried on a steel multi-truss. The framework of the structure is rolled steel reinforced with 3 in. by 3 in. by ¼ in. Tee-section rails, wall plates and purlins, and 1-in. round tie bars connected to the multi-truss. The concrete is composed of gravel chippings of a size to pass through a 1-in. ring, clean sharp sand, and Portland cement, in the respective proportions of 3½ : 2 : 1. The cement is mixed mechanically, each gauge being measured and puddled *in situ* between the forms. The concreting must be carried out from start to finish without a break. The forms remain *in situ* for three weeks after completion and are designed for mass production and quick assembly and dismantling. The interior of the shelter is covered with wall-board, which is cast in with the concrete and forms a lining which is to a certain extent soundproof. The shelter has an air-lock vestibule at one side, and at the opposite side air-tight outward opening double doors 16. Each door is composed of a steel frame with an external facing of ¼-in. armour plate, and a lining of Plymax. Silicate cotton and activated charcoal are packed between the lining and the facing. A series of Insulite windows 23 under the eaves admit daylight. To provide a supply of pure air over long periods, an air-inlet 32 and an air-outlet 36 below it are cut in the wall and have armour-plate covers. Behind the inlet opening is a sheet-metal cylindrical housing in which is a motor-driven fan, which can also be driven manually through a crank handle and gearing. Two cartridge-type filters are arranged in the housing between the inlet and the fan. To improve the circulation, the outlet has an extraction fan driven by the same motor or crank handle. (*Accepted December* 5, 1939.)

514,791. Concrete-Mixer Tank. Winget, Limited, and C. W. Stancliffe, of Rochester, Kent. (3 *Figs.*) May 16, 1938.—The invention is a water tank for concrete mixers, which may have to be refilled from various sources of supply at different water pressures. An inlet valve 1 is situated near the top of the tank. The valve casting (Fig. 2) consists of a cylindrical portion 6 divided by a partition 7 into an inlet chamber and an outlet chamber having an opening into the tank adjacent the partition.

Fig. 1.

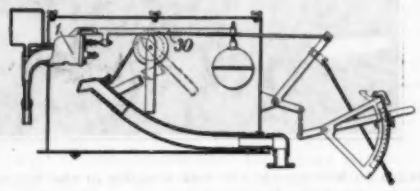
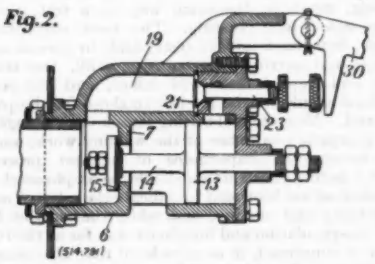


Fig. 2.



The outlet chamber is closed by a plate and in the partition between the two chambers is an opening forming a valve seating. A loosely-fitting piston 13 is mounted on a rod 14 which passes through the valve opening in the partition. A valve disc 15, faced with rubber, is mounted on the end of this rod and closes the valve opening by the pressure of the water. A side passage 19 opens at one end into the inlet chamber and leads to the space between the piston 13 and the end wall of the outlet chamber through a pilot valve. The end of the side passage 19 is closed by a plug through which passes the stem 23 of the pilot valve. A valve disc 21, of relatively small diameter, is mounted on the inner end of this stem 23 and on the outer end is threaded a knob, the position of which is adjustable. A ball-float lever 30 is pivoted on the valve casing and has an arm which abuts against the knob on the valve stem 23 so that a fall of the float lever opens the pilot valve. Assuming that the tank is empty the float lever 30 is in its lowest position, the pilot valve 21 is open, and the main inlet valve 15 is closed. When the water is turned on it flows through the pilot valve 21 into the space behind the piston 13, and moves it so as to open the main inlet valve 15. When the tank is full the lever 30 allows the pilot valve 21 to be closed by the water pressure. The pressure in the space behind the piston 13 is thus removed and the main inlet valve 15 is closed by the water pressure, the water behind the piston leaking away round its edge. The outlet can be adjusted so as to control accurately the water fed into the mixing drum. To the outlet is connected a flexible pipe inside the tank. The open end of the pipe is raised by a cable above the water level in the tank. This end is bent over so that on the pipe being lowered into the water, a siphoning action is started and full flow continues until the open end is uncovered, and the flow ceases immediately after delivery of the correct amount as determined by the position of the open end of the pipe. (*Accepted November* 17, 1939.)